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The President's Page

On invitation of President Maurice Ewing by Lloyd V. Berkner, President-Elect

The plan for revitalization of meteorological research described in this issue of the *Transactions* by Dr. Thomas F. Malone, is illustrative of the vigor of the geophysical sciences that was so evident during the International Geophysical Year. The unanimity of the scientific community in support of these plans for significant meteorological research attests not only to the urgency of the need, but also to the wisdom and broad vision of our scientific community in joining their support for essential measures for the common scientific good. As Malone's paper makes abundantly evident, means are required whereby the scientists of university faculties and research institutions can acquire access to the tools that permit the study of meteorology in its global environment.

The planning for greater opportunity for meteorological research evolved out of detailed studies and analysis extending over several years. Following a long series of conversations among the late Dr. Carl Rossby, Dr. F. W. Reichelderfer, the late Dr. John von Neumann, and their colleagues during 1955, the feeling emerged that meteorological science would become stultified for want of opportunity to carry on studies of the vital meteorological clues that nature offered. Moreover, the public interest in 'weather-modification' had led to much well-intentioned but scientifically unsound expenditure as an expression of the desire for public support of an important area of science. Yet it seemed impossible to divert this support into useful, effective, and productive scientific channels. As head of the Weather Bureau, Reichelderfer pressed the matter with Mr. Louis Rothchild, Assistant Secretary of Commerce, and they resolved to ask the National Academy of Sciences to look into the matter on the broadest scientific base. Upon request, the President of the Academy, Dr. Bronk, and its Governing Council readily responded to the Government's

request, and the Academy's Committee on Meteorology was established in October 1956.

The report of the Academy's Committee, based on long studies with scientists, educators, the Weather Bureau, and the American Meteorological Society was made on February 5, 1958, to the President of the Academy, the Assistant Secretary of Commerce, the Assistant Secretary of Defense, and the Science Advisor to the President. Meteorological scientists initiated action immediately through organization of the UCAR with the results that Malone describes.

The important point to observe is that science is quick to grasp opportunity when the channels for opportunity are opened. The unanimity of the Academy Report, and the subsequent University Committee on Atmospheric Research (UCAR) Report are a clear demonstration of the need for action originally envisaged by Rossby, Reichelderfer, and von Neumann. One writes with a sense of sadness, too, that Rossby and von Neumann cannot enjoy with us the promise of the plans as they emerge.

In the development of these plans, meteorology has derived strong support, as a member of the family of geophysical sciences; from geophysicists of all disciplines. For a strong meteorological science benefits geophysical research in all of its facets. As both the Academy and UCAR reports so clearly emphasize, the sciences of the Earth derive from physics and chemistry with the unifying language of mathematics. The fundamental equations are the same whether they be for the Earth's interior, its oceans or its atmosphere—only their applications differ somewhat from discipline to discipline. Consequently, the association of the geophysical sciences in the Union and the Academy greatly enhances their strength through their close interaction.

The global scale of the task is beyond the capacity of private support consequently the

support of the present proposals is now squarely up to the government. The unanimity of scientific purpose leaves no doubt of the need or of the measures required. There is no longer excuse for diversion of valuable funds to quasi-scientific schemes when American science has so clearly set the stage for the execution of sound

and effective scientific plans. With wise government support and imaginative direction by some of our great universities, science, our country, and the whole world can anticipate a real growth in the knowledge of our atmospheric environment.

LLOYD V. BERKNER

Twenty-First Award of the William Bowie Medal

Citation of Walter Maurice Elsasser

Prepared and Presented by MERLE A. TUVE

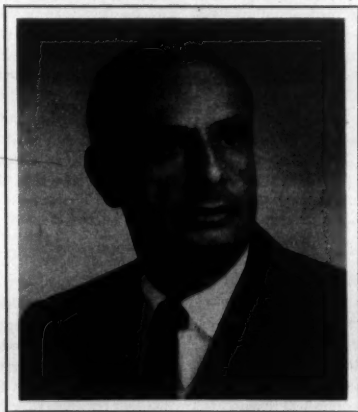
Walter M. Elsasser, Professor of Theoretical Physics at the Scripps Institution and the University of California at La Jolla, has made a distinguished record as a creative contributor to several very different fields of science. All of his activities have appeared to be natural and, almost spontaneous expressions of his devotion to theoretical physics, but each contribution has been a highly individual expression of his contemporary interests and thinking. To a sound training in theoretical physics he has always added a vigorous measure of courageously independent creativeness and the results have never been boring. For example, he has just written a book on biology. We all look forward with pleasant anticipation to additional unexpected results of the fresh stimulus of his new environment.

He was born in Mannheim, Germany, in 1904 and received his Ph.D. in Physics from Göt-

tingen in 1927. After teaching at Frankfurt and at the Sorbonne, he came to the California Institute of Technology in 1936. He became an American citizen in 1940, and participated in war research activities in meteorology and radio.

During 1945-46 he made a brief excursion into industrial research, but returned to academic work as Professor of Physics at the University of Pennsylvania 1947-50. He then became Professor of physics at the University of Utah in Salt Lake City until he accepted the Scripps' appointment last year.

Dr. Elsasser made his first contributions to quantum mechanics and the problem of waves as particles. He spent ten years immersed in wave functions, exploring atomic and nuclear energy states, and momenta, and impact and interaction problems for the primary particles



WALTER MAURICE ELSASSER
Recipient, Twenty-First Award
William Bowie Medal, May 5, 1959

of matter. With this intensive experience as a base, he launched into geophysics in 1936 as a meteorologist at California Institute of Technology and the U. S. Weather Bureau. Spectroscopic calculations, heat radiation and water vapor influences in the atmosphere were the focus of his thinking for a few years and gave him the habit of 'thinking in the round,' so to speak, on the size scale dictated by geophysics and by astrophysics instead of atoms and nuclei. Calculations of wind systems led him by 1938 to application of the same basic ideas of energy supply and Coriolis forces for the production of magnetic fields in the convective core of the Earth and in sunspots. This work was fresh and original and has gone through various elaborations in the two decades since that time. The general theoretical study of the dynamics of conducting materials in magnetic fields, more recently called magnetohydrodynamics, has occupied much of Elsasser's enthusiasm since that early effort and indeed the whole subject has been developed to a considerable extent as a result of his stimulation and ideas.

His obvious enjoyment of large-scale phenomena Elsasser has shared widely with colleagues and friends, and his critical studies of limiting conditions have served to keep his own and other lively imaginations from any casual acceptance of otherwise plausible notions con-

cerning magnetic fields, densities, and other physical aspects of the interior of the Earth, the ionosphere and outer atmosphere, the conducting gas clouds flung off by the Sun and the still larger aggregates of ionized gas involved in cosmology. He has also shown that the electromagnetic coupling of the core and mantle of the Earth operates directly to explain part of the observed fluctuations in the Earth's rate of rotation.

His recent book on *The Physical Foundation of Biology* is a challenge also typical of his friendly but analytical directness in geophysics. In this book Elsasser says he aims not to "rehash old paradoxes, but to pose in clear and distinct terms a problem, and hope . . . that establishing the precise definition of a problem goes some way toward its solution." A Professor of Biology has remarked: ". . . this book is not merely a highly critical examination of the question, Can physics explain biology? but also a re-examination of the foundations of physics in the light of those potentialities of the physical world that are realized in biological systems." On reflection, this is just the kind of basic and critical examination we would expect from Walter Elsasser. And note that he is far from done with geophysics. Few indeed today are the senior men who spend themselves for others in this kind of intimately self-sacrificing way, and we rejoice that he is one of us in geophysics.

Presentation

LLOYD V. BERKNER

Walter Maurice Elsasser, I am honored to present to you, on behalf of the American Geophysical Union and with the authority of the

Executive Committee, the William Bowie Medal for excellence in geophysical research, which is the highest award of the Union.

Acceptance and Response

WALTER M. ELSASSER

President Ewing, Vice President Berkner, Dr. Tuve, ladies and gentlemen: It is a great privilege to express my gratitude for the honor bestowed upon me tonight. I am accepting it humbly as a token of the fact always emphasized by the American Geophysical Union that it takes the cooperation of men with all kinds of background and experience, engaged in all kinds

of endeavor to solve the complex puzzles of the physics and chemistry of the Earth.

When entering geophysics in 1936 I found myself not totally unprepared since I had minored in astronomy in my Ph.D. a number of years before. It was the great Robert Millikan who helped me on my way. As he told me once, he had become very much aware of the inadequacy

of the national effort in geophysics when he served as Director of the Signal Corps Laboratories during the First World War. When, during the Second World War, I became associated with these Laboratories it was obvious that things had already become much better. By now geophysical research in America has blossomed out on a large scale indeed.

My first geophysical work was in atmospheric radiation, a subject to which I was drawn by my knowledge of spectroscopy. Having thus become more closely acquainted with some of the queries of the geophysicist, I felt intrigued by the problem of the Earth's magnetic field. At that time some of the beginnings of cosmic magnetohydrodynamics were already at hand, in the work of Chapman, Cowling, and Ferraro on solar magnetism and auroras. It struck me then that if one assumed the metallic core of the Earth to be in convective motion, not only could one account in a qualitative way for the remarkable phenomenon of the geomagnetic secular variation, with its unusual time scale, but the dynamics of such a moving fluid was ever so much simpler than that of the exosphere because it reduced to Maxwellian electrodynamics plus classical mechanics, leaving out the complexities arising in highly ionized gases. These studies were interrupted by the War and it was not until right after the War that I was able to put the magnetohydrodynamics of a spherical conductor into mathematical form. This seemed at last to permit a quantitative approach to the secular variation which had by then become known in much detail owing to the work of Vestine. It left the main problem, the possibility of a dynamo theory, still unsolved. I then realized that I had overlooked a fundamental mathematical fact, namely, the existence of two sets of aperiodic modes of the sphere, the poloidal and toroidal modes. Earlier investigators, Cowling and Ferraro, had excluded toroidal fields in the case of the Sun by means of a postulate, since these fields give rise to stresses exerted on the fluid which could not be accounted for on the then existing knowledge of solar convection. The discovery that there could be a toroidal field in the Earth's core at once led to the well-known amplifying mechanism of this field by non-uniform rotation and thus to the main step in the dynamo model, suggesting also that the dynamo

mechanism consists in a playing back and forth of magnetic energy between poloidal and toroidal fields. The feedback occurring in the dynamo is apparently quite complex; Parker has, however, succeeded in developing a plausible model for it. Bullard has shown conclusively that the westward drift of the mean magnetic field can be interpreted only in terms of the existence of a toroidal field and thus furnishes indirect but powerful evidence for the latter. The universal presence of magnetic fields in the conducting fluids of the cosmos was first theoretically explained by Batchelor when he showed that turbulence in large dimensions always leads to a mean stretching of the magnetic lines of force and hence to an increase of magnetic energy so long as this energy is small. Thus the growth of magnetic fields from small beginnings is not only possible but must be expected. This, however, would only lead to random fields, not to partly regular ones. It appeared early in my studies that the Coriolis force must be the agent which orders the amplificatory processes of the magnetic field relative to the axis of rotation of the fluid. Apart from much geophysical evidence, a qualitative but strong confirmation of this conclusion has come from the fundamental observations of Babcock on magnetic stars.

Everybody has heard of plasma, that fourth state of aggregation whose study is now so fashionable. Plasma makes numerous phenomena of magnetohydrodynamics accessible to laboratory experimentation. One can justify this theoretically by a study of dimensional scaling which shows that the large linear dimensions and low velocities prevailing in the Earth's core can be replaced by small dimensions but high velocities. It appears to me that, as techniques progress, not only plasma, but a great variety of aspects of geophysics are coming within the grasp of laboratory experimentation. Yesterday, we heard that pressures in the Earth's core can be duplicated by means of shock waves in the laboratory and that inferences can be drawn about the chemical constitution of the core. The tremendous strides which have been made in recent years in subjecting silicates and other solids simultaneously to high pressures and high temperatures are well known. Speaking of one of my own fields of interest, I have been happy to see how closely the conditions of infrared

radiation in the atmosphere have of late been duplicated by laboratory experiments. I could extend this list without difficulty, but let me merely mention here an interesting historical incident. In the early years of this century L. Prandtl, the well-known aerodynamicist built a wind-tunnel which could be heated from above, so as to permit investigation of the flow of stably stratified air. This tunnel was never used because just at that time Prandtl's group became absorbed in problems of military aviation. In recent years successful beginnings have been made in the laboratory study of flow in rotating tanks and of flow of molten metal in magnetic fields, types of experiments which have a direct bearing on geophysical questions. With the present state of technology much more work of this kind will no doubt be done once a more widespread interest is aroused. It seems safe to say

that in the study of plastic solids as well as of fluids the technological results have far outrun the potentialities of work directed toward geophysical applications.

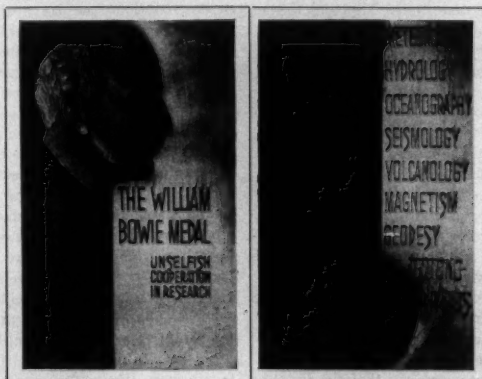
Let me conclude, then, with a note of rather strong optimism. It is a fact that many of the major problems of geophysics are still unsolved, and this is perhaps more true in geophysics than in any other physical science today. But very soon the advance of laboratory techniques should provide us with data in many fields which will allow a far more quantitative interpretation of the results of geophysical exploration than we might have hoped for only a few years ago. Having had my early beginnings in the laboratory of the physicist, I am particularly happy about this trend.

Scripps Institution of Oceanography, La Jolla, California

Previous Recipients of the William Bowie Medal

The previous recipients of the William Bowie Medal, with the dates of their awards, are as follows:

William Bowie (deceased)	1939	Walter Davis Lambert	1949
Arthur Louis Day	1940	Leason Heberling Adams	1950
John Adam Fleming (deceased)	1941	Harald Ulrik Sverdrup (deceased)	1951
Nicholas Hunter Heck (deceased)	1942	Harold Jeffreys	1952
Oscar Edward Meinzer (deceased)	1943	Beno Gutenberg	1953
Henry Bryant Bigelow	1944	Richard Montgomery Field	1954
Jakob Aall Bonnevie Bjerknes	1945	Walter Hermann Bucher	1955
Reginald Alsworth Daly (deceased)	1946	Weikko Aleksanteri Heiskanen	1956
Felix Andries Vening Meinesz	1947	William Maurice Ewing	1957
James Bernard Macelwane (deceased)	1948	Johannes Theodoor Thijssse	1958



The William Bowie Medal (actual size 2" x 3 3/4")

A National Institute for Atmospheric Research¹

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The Travelers Insurance Companies,
Hartford, Connecticut*

Abstract—A National Institute for Atmospheric Research has been recommended and supported by several representative groups in the scientific community as an essential part of an over-all expansion in atmospheric research in this country. It is proposed that the Institute be devoted exclusively to basic research and operated by a group of universities with primary support from the National Science Foundation. Its principal function will be to enhance the effectiveness of atmospheric research scientists and to bring to bear on the problems of the atmosphere the full competence of the scientific community. It will do this by fostering the vigorous interdisciplinary effort and providing the complex of large facilities and technological support that are required to make significant advances in describing the salient features of the atmosphere and in understanding the important physical processes which determine its behavior.

INTRODUCTION

From July, 1957, to December, 1958, scientists from nearly all parts of the world acted in concert to bring our geophysical environment under a critical observational study. A considerable part of the activities of the International Geophysical Year were directed toward the exploration of those portions of the atmosphere about which distressingly little had previously been known. The total impact of this major effort will not be clear until the countless thousands of observations have been analyzed and interpreted in the quiet of the scientist's laboratory or study. However, it is already apparent that information of great value was collected, and the investment of money and manpower in this scientific endeavor was a profitable one.

During the period when this extensive effort was underway, thoughtful consideration was also being given to the strengths and the weaknesses, to the problems and the requirements of our nation's program of basic research in meteorology. A searching examination of the present status of research in the atmospheric sciences

was initiated in 1956 by the action of the President of the National Academy of Sciences in appointing a Committee on Meteorology under the chairmanship of Dr. Lloyd Berkner.² The charge to this Committee was a general one. In essence, it was "to view in broad perspective the present position and future requirements of meteorological research and to recommend the general outline of a program which would accelerate progress in this important field." With six of the nine members drawn from the general scientific community and only three members from the field of meteorology, the Committee was able to view the problems before it with the desirable degree of detachment.

A series of conferences was held by the Committee in 1956 and 1957 with scientists actively working on the problems of the atmosphere and with prominent educators in the general field of geophysics. At a series of Committee meetings in late 1957 and in January, 1958, the Committee drew up its recommendations. In brief, the Committee found that the total effort in basic atmospheric research was quite inadequate when considered in terms of the scientific and economic importance of the meteorological problem and the best interests of the nation.

¹ This article is a condensation and summary of the report "Preliminary Plans for a National Institute for Atmospheric Research" prepared for the National Science Foundation by the University Committee on Atmospheric Research (UCAR), H. G. Houghton, Chairman. The original report, prepared by R. R. Braham, Jr., W. S. von Arx, and T. F. Malone, represented the summary of staff studies conducted under the direction of UCAR.

² Committee members: H. R. Byers, Vice Chairman, H. G. Booker, J. G. Charney, H. L. Dryden, C. Eckart, P. E. Klopsteg, T. F. Malone, E. Teller, and, until their untimely deaths, C. G. Rossby and J. von Neuman.

The Committee made two principal recommendations with respect to research: (1) that basic research at the universities and kindred institutions be substantially augmented immediately, and (2) that a National Institute for Atmospheric Research be established. Because the matter was clearly one of national interest and the emphasis was on basic research which might not carry with it specific or short-range economic gains, the committee suggested that primary support for this expanded program should come from the Federal Government.

In its deliberations, the Committee had noted that progress in atmospheric research was inextricably linked to the problem of education and scientific manpower. The Committee made two further principal recommendations dealing with these questions: (1) that the American Meteorological Society substantially expand its program of stimulating interest in meteorology as a field for scientific and professional activity of unusual challenge and opportunity, and (2) that the departments of meteorology at the universities should form an inter-university committee to consider matters such as curricula, student recruitment, fellowships and textbooks.

Response to these recommendations was immediate and vigorous. By the end of February, the universities had organized the University Committee on Atmospheric Research (UCAR) and initiated a series of meetings that were to continue throughout the year. This Committee was made up of the chairmen, or their designees, of the university departments of meteorology that offered the doctorate in meteorology, and also included a representative of one university active in research on the physics of the high atmosphere³.

The objective which UCAR set for itself was very similar to the charge given to the Committee on Meteorology of the National Academy of Sciences, but it was clearly agreed at the outset that any conclusions that might be reached must be arrived at independently of

the recommendations made by the Committee on Meteorology.

At UCAR meetings in February, March, and May discussion revolved around five principal considerations: (1) the need and urgency for an expansion in basic research on the atmosphere; (2) university research; (3) a national institute for atmospheric research; (4) education and scientific manpower in meteorology; and, as a consequence of decisions reached on these four points, (5) sources of support.

There was complete concurrence on the urgency for strengthening and expanding basic research if the scientific and economic needs of this country were to be met and the national interests to be served. There was also unanimous agreement that the universities must continue to play a leading role in atmospheric research.

With respect to research at the universities, UCAR presented three specific recommendations: (1) that the university programs be strengthened and stabilized immediately by increasing research budgets \$1,500,000 to \$2,000,000; (2) that plans be made by supporting agencies to double the current level of support within three to five years; and (3) that steps be taken to insure long-term stability of support, to reduce fractionation, and to provide greater freedom and flexibility in the use of funds for basic research.

In considering the need for a National Institute, UCAR gave thoughtful and deliberate consideration to the following questions: What is the need for such an Institute? Why cannot the conceivable needs for an Institute be met in existing university and government laboratories? What specific kinds of research require the existence of an Institute? Should an Institute be more than just a collection of large facilities? If so, what types of research not requiring facilities should be carried on? Are the scientific manpower resources sufficient to staff an Institute with the calibre of scientists necessary for it to contribute effectively in basic research? What can be done to provide a highly competent permanent staff? What proportion of the total staff should be visiting scientists? Would an Institute weaken the position of the universities by competing with them for funds and personnel? Would an Institute be of assistance in attracting to the study of atmospheric problems the physicists, mathematicians, chemists,

³ Participating universities were Johns Hopkins University, University of Wisconsin, University of Chicago, University of Washington, New York University, Florida State University, University of Michigan, University of Arizona, A and M College of Texas, University of California (UCLA), Pennsylvania State University, Cornell University, St. Louis University, and Massachusetts Institute of Technology.

astronomers and engineers required for a true interdisciplinary effort? In a report summarizing their deliberations, UCAR listed four compelling reasons for the establishment of a National Institute for Atmospheric Research:

(1) The need to mount an attack on the fundamental atmospheric problems on a scale commensurate with their global nature and importance.

(2) The fact that the extent of such an attack requires facilities and technological assistance beyond those that can properly be made available at individual universities.

(3) The fact that the difficulties of the problem are such that they require the best talents from various disciplines to be applied to them in a coordinated fashion, on a scale not feasible in a university department.

(4) The fact that such an institute offers the possibility of preserving the natural alliance of research and education without unbalancing the university programs.

In urging an expanded program of atmospheric research UCAR was not unmindful of related, as well as consequent, problems in the area of scientific manpower and education. Although it had the firm conviction that an institute of a high quality of excellence, properly equipped with the facilities required to make scientific efforts fruitful, would be a powerful magnet attracting capable individuals in the scientific community to the challenging scientific problems of the atmosphere, it was keenly aware that vigorous steps would have to be taken at once to guard against the inviting but dangerous assumption that competent scientists 'can be found somewhere' to carry on the expanded program at the universities and the scientific work of the Institute. To meet this problem, UCAR initiated through the American Meteorological Society with support from the National Science Foundation a program of visiting lectureships, intended to bring to colleges and universities, research meteorologists to stimulate the interests of physical science majors in the exciting problems of the atmosphere and make known to them the opportunities available to graduate students and research scientists. With support from the Alfred P. Sloan Foundation, attractive graduate fellowships in meteorology have been provided for gifted science majors interested in atmospheric research.

While UCAR was cognizant of the desirability of broadening the base of support for fundamental research in meteorology, it also recognized that the nature of the program it was recommending required support from the Federal Government. Moreover, UCAR felt that the existence of a high degree of national interest in the problems of the atmosphere was ample justification for requesting this support. Because the contemplated expansion was in the area of basic research, it was considered preferable that this support be provided through the National Science Foundation.

With strong support from the presidents and governing bodies of the universities, plans were laid for the formation of the University Corporation for Atmospheric Research to foster support of meteorological research at the universities, to organize and operate a National Institute for Atmospheric Research, and to encourage the education and training of the personnel required to carry on an expanded program of atmospheric research. Incorporation and organization of UCAR was completed in April, 1959.

To lay before the community of scientists engaged in atmospheric research the question of a National Institute for Atmospheric Research, to determine the general outline of the research program that should be carried on at the Institute, and to provide the background for the necessary facility and budgetary planning, seventeen two-day conferences were arranged, with each conference devoted to a particular aspect of atmospheric research and attended by from five to fifteen prominent authorities in that aspect. Conference topics were:

- Atmospheric Chemistry
- Atmospheric Electricity
- Atmospheric Radiation
- Cloud Physics
- General Circulation
- Hydrodynamic Analysis
- Hydrodynamic Models
- Interaction of Ocean and Atmosphere
- Meteorological Instrumentation
- Meteorological Use of Rockets and Satellites
- Ozone
- Severe Storms
- Statistical Methods
- Tropical Meteorology
- Turbulence and Convection

Upper Atmosphere

Use of Electromagnetic Radiation as a Meteorological Probe

The participants at each of these conferences were asked to review the state of knowledge in the field under discussion, to consider the role that the Institute might play in basic research in that area, to recommend the kind of facilities as well as the type of intellectual attributes the Institute should have to extend the frontiers of knowledge, and to give their opinions on the concept, the function, the organization, the advantages and the disadvantages of an Institute. Out of this series of conferences and as a result of the deliberations of UCAR, there has emerged a concept of the Institute, its scientific program, and the general outline for the organization and operation of the Institute.

THE CONCEPT OF A NATIONAL INSTITUTE FOR ATMOSPHERIC RESEARCH

There was unanimous agreement among all groups which considered the problem that the Institute should be concerned exclusively with basic research. This policy was recommended as a consequence of the general recognition that there is need in atmospheric research for work to progress on a broader basis than that which is possible under the constraints imposed on applied research and development responsive to operational requirements. It is inevitable that applications will arise from research conducted at the Institute, and the potential applications will actually influence to some extent the scientific program at the Institute. But in the long run, it seems certain that applications will be more far-reaching and effective if they come as by-products of undirected efforts to acquire knowledge. Thus the scientific program of the Institute will be centered on a search for the solutions of broad and fundamental problems of the atmosphere, with emphasis on those requiring extensive interdisciplinary participation or facilities beyond the capacities of individual university departments.

Since the principal work at the Institute will concern scholarly investigations, the core of the Institute should be composed of a variety of highly competent research scientists from all parts of the world, which is to say that the Institute must possess all the attributes of an international intellectual center. The intellectual

climate of the Institute should be broadly based on a variety of disciplines and technical skills. The scientific problems of the atmosphere do not fall within the usual boundaries of scientific fields; the atmospheric sciences are, by nature, interdisciplinary. Therefore, in addition to meteorologists it would be appropriate to encourage, for example, classical physicists, mathematicians, chemists, and engineers to participate in the scientific program of the Institute.

It is not sufficient, although quite necessary, that the Institute be characterized by superb intellectual strength. One of the principal justifications for establishing the Institute is to place at the disposal of the scientists the array of powerful research tools that are required to carry on fruitful investigations of the atmosphere. No single major facility is required, but rather it is a complex of large facilities that must frequently be used in coordinated and integrated efforts that is necessary to make significant advances toward a proper understanding of the atmosphere. These include, for example, a flight facility comprised of several different and complementary types of aircraft appropriately instrumented so that they can serve as platforms for sensing devices, a well-equipped instrumentation laboratory to design and construct the specialized sensing devices required for research utilization of aircraft, rockets and satellites, an electronic computer facility to reduce the tremendous volume of observational data to meaningful physical variables, ground-based and airborne equipment for probing the atmosphere by electromagnetic radiation techniques, and the adequate technical and logistical support to assure productive operation of these large and expensive research tools. These same tools, deployed in fragmented, project-type research, operating without the freedom and stability envisioned for the Institute, and lacking the scientific guidance of the diverse and strong theoretical core of the Institute, could certainly not be used nearly as effectively and economically as at the Institute.

The Institute, then, is to be thought of as a center at which high scientific competence and consummate technological skill can be combined in a free and natural alliance to master our atmospheric environment. Naturally, no forced marriage of these two qualities is considered. Provision must be made for a research environ-

ment conducive also to quiet contemplation. Nor is it intended, in citing as examples those facilities which stress airborne probing platforms of various kinds, to imply that the scientific program of the Institute will have a bias toward this particular kind of research. The large-scale electronic computer facility will find wide application in advancing purely theoretical studies and an extremely good library is regarded as one of the essential facilities of the Institute.

The facilities of the Institute are to be available on an equal basis to those qualified scientists who have interest in the fundamental problems of the atmosphere, without regard for institutional or organizational affiliation. In addition to a distinguished staff permanently attached to the Institute, it is expected that an equal number of scientists from universities and from private and government research laboratories will affiliate themselves with the Institute on a transient or semi-permanent basis. Many of the problems of the atmosphere are such that a visiting scientist may profit from residence in the Institute for periods as brief as a few months to as long as several years before returning to his permanent position. It is recognized that many parts of the scientific program of the Institute will acquire direction and continuity through its permanent staff, but the nature of many of the problems to be solved is such that temporary association with the program of the Institute could have lasting effects as well as being immediately productive both for the Institute and for the visitor. The Institute can play an important role as a stimulus to the general intellectual activity in atmospheric research in this country.

It is expected that the Institute will complement the work of the universities. The function of the university is to extend and disseminate knowledge. One function of the Institute is to enhance the effectiveness of the university scientists concerned directly or indirectly with atmospheric problems. Since there is a traditional alliance between teaching and research, it is to be expected that the Institute will strengthen this alliance and act to preserve a proper balance of these functions in the universities by assisting them in meeting the requirements for large research facilities. It is essential to the success of the Institute that it be integrated

into the university community and that participation in its activities be on a university-wide basis and not be narrowly restricted to departments of meteorology. It is expected that graduate thesis research will be pursued at the Institute when there is a requirement for its facilities and appropriate supervision can be arranged to satisfy the specific requirements of the university concerned. Opportunities for postdoctoral research and study may be extended to promising young men from all countries and all relevant disciplines.

The Institute will be operated under the direct supervision of a Scientific Director, acting within the spirit of broad policies set by a Board of Trustees composed of one scientific and one administrative representative from each of the sponsoring universities and several Trustees-at-Large. It will be physically and administratively independent of any single university. Standards for permanent staff appointments will be the same as those at a university of high standing.

Careful thought has been given to the rate at which an Institute of this kind could be established. A judicious compromise between prudence and a lively sense of urgency over bringing atmospheric research up to a reasonable level suggests that about six years will be required to achieve full-scale research operations at the Institute. The limiting factor is the rate at which scientific manpower can be acquired.

Many of the fundamental problems of the atmosphere are not likely to be solved without sustained effort. Substantial progress toward a satisfactory understanding of the atmosphere will probably have to be measured in decades rather than in years. It is essential that support for the activities of the Institute be of a stable and long-term nature even though some problems are susceptible of immediate solution given the proper scale of effort.

RESEARCH OBJECTIVES OF THE INSTITUTE

The scientific problem of meteorology—One of the most important characteristics of the atmosphere is that it is a thermally active hydrodynamic system, influenced by the Earth's rotation and by a combination of internal and cosmic forces. The fluid consists of a mixture of gases in which a number of trace substances play important roles. Many factors operate

simultaneously and interact with each other. As a whole the gas fraction is compressible, non-homogeneous, and viscous and is bounded below by geometrically and thermodynamically inhomogeneous surfaces and above by the outer reaches of the solar atmosphere.

The atmospheric envelope rotates with the Earth, but does not rest quietly upon it. These minor internal motions of the atmosphere, the winds, are in fact small departures from rather large absolute velocities. Winds are induced by a non-uniform distribution of energy sources and sinks, which in many cases are formed and dissipated at various rates by the internal motions themselves. Air circulation patterns in the atmosphere range in scale from the circumpolar vortex at mid-tropospheric levels, down through the migratory cyclones and anticyclones, hurricanes, tornadoes, and meso-scale wind systems, and on into the convective cloud currents, and finally into small-scale turbulence. One of the central problems of meteorology is to explain the existence of this spectrum of atmospheric disturbances and the interactions among them. Present knowledge is fragmentary and no unified theory of air motion has yet been developed.

Intimately linked to the phenomenon of air in motion is the matter of energy distribution. Sources and sinks of energy are variable in number and strength and exist mainly in response to the disposition of short-wave solar radiation, the flux of outgoing long-wave radiation, the latent heat involved in phase changes of water substances, and on the flow of sensible heat at the boundary between the lower atmosphere and the oceans or land. Knowledge of the radiative transfer of energy in the free atmosphere suffers acutely from a lack of observation, although the theoretical and observational tools exist to acquire the needed information. The thermodynamics of clouds is but poorly understood. The energy exchange process between the atmosphere and the ocean (which dominates the surface of the earth) is known only very crudely. Until knowledge of the atmospheric energy budget is placed on a secure foundation, it will be extremely difficult to make much headway toward a real understanding, much less the prediction, of air motion or its consequences.

In addition to being thermally active, the atmosphere is the seat of many physical and chemical processes of importance not all of which are clearly understood. For example, the photochemical processes by which the ionization and recombination of gaseous components is achieved are only partly known. The chemical equilibrium of ozone in the upper atmosphere has a profound influence on biological processes on the ground as well as being a possible link between fluctuations in the emission of ultraviolet energy from the Sun and atmospheric motion of lower levels. The distribution and decay of natural and artificial radioisotopes, the carbon dioxide and nitrogen cycles in the atmosphere, and the processes by which particulate materials are diffused and removed from the atmosphere are problems which have assumed ecological significance. The phase changes of water substances and the growth of cloud particles to raindrop size offer physical-chemical problems which are clearly of practical as well as scientific interest. The fair weather electrical field in the atmosphere and the mechanism of charge separation which transforms it under stormy conditions is a problem requiring further elucidation. The characteristics of the atmosphere which influence the propagation of electro-magnetic radiation over the entire spectrum of wave lengths are of obvious practical significance and of scientific interest in their own right.

The atmosphere forms a major part of the environment to which this life is sensitively responsive. To this extent the atmosphere has the characteristics of a great natural resource. The micro-climate influences the intricate balance between plant life and lower forms of animal life. Plant growth and productivity react sharply to a complex combination of temperature and moisture conditions. Human and animal life, and even their evolutionary progress, are influenced by their reactions to the atmospheric environment.

In other respects floods, hurricanes, tornadoes, droughts, frosts, and the problems of air pollution have all, on occasion, influenced modern society. The economic losses accompanying these atmospheric catastrophes can be staggering. But the really tragic part of these occurrences is that they are produced by natural

phenomena that we do not clearly understand and cannot predict with the necessary degree of certainty.

On first consideration, the scientific problem of the atmosphere seems to be incredibly complex. However, if it is analyzed and subdivided into an orderly series of problems, it becomes less formidable. There is a logical ordering of the several parts of the atmospheric problem and it is convenient to list the parts as a framework within which it has been suggested that the research at the Institute might be structured. In simplest terms they are these four: description, understanding, prediction, and control. For the atmosphere, as for any physical system, the capacity to understand is predicated on the capability to describe; the ability to predict in a really satisfactory manner is dependent on the capacity to understand and in a scientific sense is a measure of that understanding; intelligent control must rest firmly on an ability to predict—else the efficacy of measures by which control is attempted will remain in doubt because of uncertainty as to the course the atmosphere would have taken if left to its own devices. However, there is not an absolute dependence for the solution of one of these problems on the solution of the problem which precedes it. Some degree of skill in prediction exists without complete understanding, and limited success in local control of weather is recognized even in the absence of an ability to predict with pinpoint precision. In spite of the fact that by far the major portion of meteorological observation is directed to routine quantitative description of successive states of the atmosphere for purposes of weather forecasting, the level of understanding that has been achieved is remarkable and is not to be deprecated because of its shortcomings.

In line with the policy to stress basic research at the Institute, primary attention should be given to the matters of description and understanding. There was general agreement that, in the long run, this is also the most promising avenue along which to approach the admittedly important task of improving weather prediction and of resolving the important question of weather control. While scientific experiments in weather prediction and control are not precluded, were they to be made the primary ob-

jectives of the Institute its scientific program would suffer from hobbling restrictions right at the outset.

Research program of the Institute—In the context of the brief discussion concerning the nature of the atmospheric problem given above and on the basis of the material collected during the series of research planning conferences it is possible to outline in broad terms the general characteristics of the research program currently envisioned for the Institute and to indicate the facilities and other attributes of the Institute which would be required to enable it to play a unique role in the overall atmospheric research effort. From the point of view of providing some structure to the scientific program of the Institute, the research objectives can be classified as being directed toward four broad areas of inquiry. Each area is concerned with one or more fundamental problems in the atmosphere. These four aspects will be discussed in turn.

(1) Atmospheric motion. This includes the entire spectrum of internal wind systems, varying in scale from the general global circulation down to turbulent eddy elements. This research area includes the anticyclonic wind systems, tropical and extratropical cyclones, hurricanes, tornadoes, squall lines, and mesoscale wind phenomena.

From the viewpoint of understanding, the problem of air motion deals with hydrodynamic flow in an open thermodynamic system. There have been important developments in theoretical work in this area during the past decade and the time appears to be propitious for a concerted effort to push forward with the fundamental studies that are expected to yield a vastly improved understanding of air motion. The intellectual resources required here are competence in mathematics and classical physics. The particular facility that is required is a large-scale electronic computer. Advances in the theoretical treatment have benefited tremendously from the availability of high-speed, large-memory computers and it is considered to be important that a proper balance be maintained between advances in theoretical work and advances in computer technology. There have also been significant developments in the application of modern statistical methods to the

problem of air motion, both from the theoretical point of view and as a result of the increasing use of electronic computers. There are extensive requirements for a computer of the most advanced commercial design to be available exclusively for basic research on hydrodynamic and statistical analysis. This urgent need involves the availability of a computer laboratory complete with applied mathematicians and programmers to do the necessary analysis and coding. The likelihood exists that hydrodynamic and statistical methods can be combined to develop a form of statistical mechanics that will be of considerable importance in the analysis and understanding of air motion.

Hydrodynamic models have been developed to a high degree of sophistication in recent years, primarily as an analytical tool rather than as an atmospheric analogue. At present there is no urgent need for model facilities that cannot be provided at the universities, but instrumentation and data-reduction facilities are needed. There is general agreement that laboratory model work should be an integral part of a concerted program to attack the fundamental hydrodynamics of the atmosphere.

On the side of description, two extremely promising research tools have been developed in recent years, but neither has found the degree of application in atmospheric research that their capabilities clearly suggest. The first is instrumented aircraft and the second is microwave radar.

The very great potential of instrumented airplanes as diagnostic devices for research studies has been amply demonstrated by the work of the National Hurricane Research Project and there are obvious extensions to the study of mid-latitude wind systems and to tornadoes and mesoscale phenomena which have not been made simply because these large and expensive facilities have not been readily available. A great need exists for a flight facility, a supporting instrumentation development group and a data-processing laboratory provided on a stable, long-term basis. What makes this need particularly urgent at the present time is the fact that knowledge of atmospheric wind systems has arrived at the stage where it is possible to ask meaningful physical questions, design an observational mission involving aircraft to answer those questions, and exploit the full capa-

bilities of aircraft serving as platforms for sensing devices in answering the questions. This circumstance opens up exciting prospects for increasing our understanding of air motion.

The great advantage of radar lies in the fact that it permits a three-dimensional description of the field of motion. To the extent that this motion influences the distribution of precipitation particles, the efficacy of this tool has been established. It is indispensable in observational studies of hurricanes, tornadoes, mesoscale phenomena, and cloud circulations. The need is for equipment especially designed for atmospheric research and for closer liaison between scientists with a primary interest in radar and scientists with a primary interest in the atmosphere. For the most part, radar equipment used in atmospheric research was designed either for an entirely different purpose or for operational use in meteorology. Even the equipment which has been made available lags significantly behind current technological developments in radar.

To these two research tools for describing air motion can be added a third: the use of isotope and radioactive tracer techniques. These methods are particularly useful for studying the gross features of the general circulation and the mechanism and rate of exchange between the stratosphere and the troposphere. The use of decay products of radon as a tool for finding tropospheric air in the stratosphere requires the sampling of large volumes of air in the upper layer and is another aspect of atmospheric research in which aircraft are needed. The attractive possibilities of using tracer techniques have not yet been explored to the extent which is warranted, and work in this direction should accompany other activity in the study of air motion.

Finally, it may be mentioned that certain problems of the upper atmosphere, for example, those concerned with the ionosphere and the auroral glow zone, are beginning to require more attention to the motion at these levels. It is likely that a fruitful cross-fertilization of ideas and techniques could be achieved between the hydrodynamicists working on the atmospheric motions in the troposphere and the physicists concerned with magnetohydrodynamics in the upper portions of the atmosphere.

(2) Energy exchange processes in the atmosphere. Studies encompassed by this area include

the nature, distribution and flux of particle energy, short-wave radiation, long-wave radiation, turbulent mass transport and the exchange of sensible heat between the atmosphere and the underlying surface, as well as the latent heat involved in the phase transformation of water.

There are four important reasons for designating atmospheric heat budget as one of the broad, fundamental problems that should be attacked at the Institute. In the first place, the development of mathematical models of atmospheric motion has now reached the stage at which it is feasible to introduce the energy equation in explicit form. To do this with any degree of reality compounds the analytical problem tremendously, and much more information is required than is now available on the distribution of heat sources and sinks in the atmosphere. To acquire this knowledge, a major effort addressed to the problem of the atmospheric heat budget is required. In the second place, meteorological satellites will place in the hands of the atmospheric scientist a new and remarkably powerful tool for viewing the heat balance problem in its global entirety. To exploit the information which will become available and to develop the techniques of measurement and data reduction and interpretation which will be necessary is going to require a larger effort than now exists. Thirdly, since the ocean surface underlies the atmosphere over nearly three-quarters of the world, it is clear that a quantitative explanation of the heat budget of the atmosphere must be, to a substantial extent, a joint endeavor of atmospheric scientists and oceanographers. The expanding interest and activity in oceanographic research make the present time propitious for a far more comprehensive study of the energy exchange at the boundary separating the gaseous part of the Earth's envelope from the liquid part. Finally, the physical linkage between the heat budget and the general circulation of the atmosphere is such a close one that any hope of effective climate control is likely to lie in alteration of some aspect of the heat budget. One of the most promising methods for the scientific analysis of climatic variation and the possibilities of controlling this variation is to experiment with mathematical models of atmospheric motion under a variety of distributions of energy inputs. But before this can seriously be at-

tempted, it is essential that fundamental knowledge of heat transfer processes in the atmosphere be extended.

The intellectual resources required for this work draw upon the disciplines of physics, chemistry, and mathematics. Solutions to the problems of atmospheric radiation require competence in classical physics, particularly in spectroscopy. Knowledge of chemistry is needed in dealing with the energy balance of the ozone layer and the upper atmosphere. Physical and mathematical skills are required in treating the matter of the turbulent transport of heat between the atmosphere and its underlying surface—land or water.

Research facilities that are needed here include a spectroscopic laboratory for the study of absorption and emission characteristics of atmospheric constituents, instrumented aircraft to make radiation measurements and to obtain horizontal and vertical profiles of the ozone distribution, a large-scale computer for theoretical calculations and reduction of observational data, and an instrumentation laboratory for equipment development. Quite clearly, rockets and satellites will play an important role as platforms for radiation sensing devices, but it was recommended that the Institute should work in cooperation with agencies that already have rocket and satellite facilities and should concentrate on the design of scientific experiments to be conducted with these vehicles, on the development of the sensing devices and on the analysis and interpretation of the observations from these probes. These are areas in which there are important needs at the present time.

A particularly important part of the heat budget problem is found in tropical latitudes. It was pointed out that the flight facility of the Institute could help fill a large gap in our knowledge in this area by conducting "expedition"-type experiments designed to yield significant information over this portion of the globe from which data coverage now is distressingly sparse.

The role of latent heat in the atmospheric heat budget overlaps into the third broad problem area of the Institute and will be mentioned in the next section.

(3) Water substance in the atmosphere. The objective here is: to understand the fundamental physical and chemical properties of water in

the liquid, solid, and gaseous phases; to understand the micro- and macrophysical meteorological processes responsible for the generation, internal structure, and dissipation of clouds; to understand the micro- and macrophysical processes responsible for the formation, structure, and efficiency of all forms of precipitation; and to understand the thermodynamic interaction between a cloud or a cloud system and the surrounding atmosphere.

There are several reasons for emphasizing this subject as a broad problem area for fundamental research at the Institute. In the first place, the role of water substance in the atmosphere is a crucial one. It has a profound influence on the distribution of energy sources and sinks by virtue of its effect on radiation processes and because it is continually releasing or taking up heat from the atmosphere as it changes phase. Secondly, knowledge about water substance in the atmosphere has advanced to the stage at which further progress will be accelerated or slowed by the extent to which recourse can be had to actual observational data obtained from direct measurements in the atmosphere. Thirdly, these observational studies are now both practicable and feasible with the use of instrumented aircraft, radar, and modern data-processing equipment. Finally, from national economic considerations, the water resources problem is already a critical one and will become even more critical during the next few decades. Recent experimentation has raised the cautious hope that man may one day be able to exert some influence in the management of this natural resource. It is abundantly clear, however, that this hope will not be realized until fundamental knowledge about water substance in the atmosphere is substantially expanded.

Airborne field studies are required to establish the nature, abundance and size distribution of condensation and freezing nuclei, the droplet-size distribution, liquid water content, temperature and electrical effects in cloud systems, the wind field, the albedo and the radiation budget above, below, in and around clouds and cloud systems, and thermodynamic interactions between clouds and their environment, and the phase, drop-size distribution and total liquid water content of precipitation elements in and below clouds, and the interaction between the electrical field in and about clouds and the pre-

cipitation process. There is more involved here, however, than merely sending aircraft up to take measurements. There are deficiencies in currently available instrumentation that need the attention of a group of high competence. These deficiencies are not fundamental and the technology exists to correct them. This technology has simply not been applied because of the disjointed way in which much of cloud physics work has been carried on. Moreover, the development of sensing systems must take place with regard for compatibility between the data-gathering procedures and the computing facilities for reduction of these data.

To complement and supplement the information obtained by sensing probes mounted on are required. Currently available radar systems airplanes, both ground-based and airborne radar leave much to be desired from the standpoint of cloud physics studies, but here again the technology exists to improve their performance materially.

For laboratory studies, a cold chamber, a vertical wind tunnel, facilities for the construction of kinematic cloud models and equipment to measure the radiation characteristics of water substance over a range of pressures, are included among the basic research requirements.

A relatively neglected area that deserves more attention is the study of the hydrologic cycle by the analysis of isotope ratios. But first, answers must be obtained for questions such as whether or not the changes in the ratios of O^{16}/O^{18} and H/D follow the same equilibrium distillation process in nature that they do under special laboratory conditions. The pressing need in the field of isotope tracer analysis is to bring together the chemist and the cloud physicist.

Fundamental theoretical investigations are needed of the basic physics of water in all its forms, the physical-chemical aspects of nucleation, and the physics of cloud droplet growth. The requirements for a large-scale electronic computer in theoretical studies of cloud droplet growth are as severe as in any other area of the atmospheric sciences.

Experimental field studies concerned with modification of precipitation processes in the atmosphere have been recommended as a part of the Institute's research program in this area, but the purpose of these experiments should be to elucidate the physics of the precipitation

mechanism rather than simply to see if it is possible to augment the rainfall at the ground.

From the brief account of some of the major scientific problems connected with the study of water substance in the atmosphere, it is apparent that a vigorous interdisciplinary effort is required in this field just as it is in the previous two broad problem areas.

(4) Physical phenomena in the atmosphere. There are phenomena in the atmosphere of great interest and importance which do not play as direct a part in atmospheric motion as do radiation phenomena and water substance. These include, for example, electrical, chemical, optical, and acoustical phenomena and certain physical processes in the upper atmosphere. Study in some of these fields has been carried on somewhat independently of the main stream of atmospheric research, yet these phenomena are integral parts of the scientific problem of the atmosphere and it is generally agreed that they should be included in any comprehensive research program aimed at a better understanding of the atmosphere.

Over and above their fundamental scientific importance, there are three reasons why provision should be made for inclusion of problems in this general area in the scientific program of the Institute. The first is that the world-wide activities of the International Geophysical Year have resulted in the amassing of an astounding volume of extremely valuable scientific data. The reduction, analysis and interpretation of these data are going to require the competence of a strong interdisciplinary group equipped with excellent facilities for large-scale data processing. While it would be highly undesirable to concentrate all of the effort in analyzing IGY data in one place (and would not be possible even if it were attempted), the Institute, as an international intellectual center with a marked interdisciplinary flavor and a first-rate computational laboratory, could serve as a focal point for bringing together and coordinating the several disciplines involved and make an important contribution to the effective utilization of these data—many of which are concerned with atmospheric phenomena which fall into the general category under discussion. Secondly, man's activities in consuming fossil fuels during the past hundred years, and in detonating nuclear weapons during the past decade have been

on a scale sufficient to make it worthwhile to examine the effects these activities have had upon the atmosphere. Reference is made here to the still unsolved question of whether the carbon dioxide content of the atmosphere is increasing as a result of combustion processes and the even more elusive question as to possible changes in the Earth's electrical field as a result of nuclear explosions. Thirdly, by nature most of these problems fall exactly into the realm of basic research and many of them require facilities on the scale envisioned for the Institute as well as an interdisciplinary approach. A few examples will be cited here.

It was pointed out by the participants in the conference on the upper atmosphere that a pressing need in auroral and airglow research is for laboratory and library research to obtain a better understanding of the fundamental physics which is involved. It was further emphasized that this will require bringing together in one place people from many disciplines which have not yet been drawn into these investigations. The physical properties of the atmosphere between the limit of balloon soundings and the ionosphere are just beginning to be measured by rockets, but there is no concerted effort to exploit the information obtained from these vehicles. Measurements in this region may be of critical importance in establishing possible effects of solar disturbances on tropospheric weather. Another problem of the upper atmosphere that has been described as being neglected is the determination of the variables of state above 100 kilometers.

The study of atmospheric electricity has lacked facilities for the field investigations on a scale to determine more than the gross features of the Earth's electrical field and its temporal variations. Moreover, there was agreement from participants of the conference on atmospheric electricity and the conference on the upper atmosphere that the broad field of study concerned with electrical phenomena in the atmosphere has suffered seriously from a traditional but scientifically indefensible division into upper and lower atmospheric phenomena.

The thunderstorm and associated phenomena are among the most important problems in atmospheric electricity yet existing basic knowledge of atmospheric electrical effects and the instrumentation for making the basic measure-

ments are so inadequate that, at the present time, it would be difficult to justify a large field project for the sole purpose of studying electrical effects in thunderstorms. The Institute could be of great help in this area by developing adequate instrumentation for such a study. The need for field studies of this kind can be inferred from the fact that there is at the present time no generally accepted explanation for a process so basic as the separation of charge in an incipient thunderstorm.

There has even been evidence presented that the role of electrical phenomena in the atmosphere may not be as passive as heretofore believed. The possibility cannot be completely discounted that electrical effects may be of some influence in the precipitation process. Should this be verified, another intriguing possibility would be opened up for exerting some degree of control over the weather by influencing the electrical field in the atmosphere.

The establishment of 'bench mark' stations to measure long-period changes of the electric field in a representative number of atmospheric columns is urgently needed in order to investigate long-term effects of nuclear explosions on the Earth's electrical field. A related question which needs attention concerns the effect of nuclear weapons tests on the isotope balance in the stratosphere. An answer to this question is difficult because knowledge is so limited about the natural production of isotopes in the atmosphere. Research on this fundamental scientific problem also involves securing samples of air from columns extending into the stratosphere.

Other fundamental problems that require attention in the field of atmospheric chemistry include: the isotopes of water, the carbon dioxide and nitrogen cycles, the properties of oxygen, the general geochemical balance in the atmosphere, the escape of substances from the atmosphere, and the origin of the atmosphere.

The sampling of chemical and electrical problems given above is merely intended to be suggestive of a class of problems which have been suggested as the kind that would provide a desirable breadth and depth to the program of fundamental research at the Institute. Some of these investigations require large-scale facilities, such as computers and aircraft, or technological support, for example, development of instrumentation. Others need the refreshing

thinking that can result from interdisciplinary collaboration. Either need qualifies a problem for consideration at the Institute.

INSTITUTE ORGANIZATION AND FACILITIES

Institute laboratories—The total resources of the Institute may reasonably be divided into two kinds: people and facilities. Care must be taken in further subdivision, lest an undesirable degree of compartmentalization be artificially imposed. Traditionally, meteorologists have been grouped by primary interest into a half dozen or so different kinds of meteorologists. This is considered to be undesirable at the Institute at which the goal is to achieve the fundamental unity of the atmospheric sciences while respecting the identity of the basic disciplines which have a part to play in atmospheric research. Since some grouping of people is necessary, it has seemed desirable to do this by basic disciplines. This suggests that a physical laboratory, a mathematical laboratory and a chemical laboratory comprise a suitable structure for the organization of the Institute. In response to the urgent need for emphasis on instrumentation, provision has been made in the physical laboratory for basic research on instrumentation. Progress in this area, however, will involve all three laboratories.

It is unlikely that this subdivision will result in establishing impediments to an interdisciplinary effort, since all three laboratories will be concerned in varying degrees with the four fundamental problem areas outlined in the preceding section. In addition they will share in common the facilities to be described below.

These facilities represent the basic tools required in the four general problem areas selected as fields for fundamental investigation at the Institute. The largest single facility is the group of aircraft for which there is an almost universal need in the descriptive aspects of atmospheric research. Only the major facilities will be described here and it should be emphasized that the facility requirements will depend on the interests of scientists actually engaged in research at the Institute and that even their requirements will change as their work progresses.

Institute facilities—(1) Flight facility. Airplanes are needed at the National Institute for Atmospheric Research to provide airborne plat-

forms suitable for carrying out scientific measurements of atmospheric variables, and for conducting experiments aimed at furthering our understanding of the atmosphere. Research in many areas is lagging because of a lack of such facilities.

The proposed minimal flight facility for the National Institute is as follows: two Cessna 310's (or equivalent), two Convairs (or equivalent), three DC-6's, and two B-57's. This proposal is based upon planes available in 1958—it is likely that the actual complement of planes at the Institute will differ somewhat from this list. It is not considered wise for the Institute to invest in single engine light planes because of their limited size and electrical power for scientific equipment, and their restriction to daytime CFR conditions. Any need for these planes at the Institute should be met through local rental.

These airplanes will be permanently instrumented for measuring those variables which are common to almost all kinds of atmospheric problems. In addition, power supplies and recorder systems will be large enough and flexible enough to accommodate additional instruments needed for certain special studies. The variables to be measured on all flights include wind direction and speed at flight level, air temperature, atmospheric pressure, height above surface, air water-vapor content, 'D' value, cloud water content, and radar cloud coverage. (The light twins will not be equipped for some of these measurements.) Among variables which will be measured only on special flights one can list precipitation water content, cloud droplet spectra, precipitation particle spectra, air turbulence and strong vertical motions, radar cloud structure, atmospheric electricity, condensation nuclei, atmospheric particulates, ice nuclei, land-sea surface temperatures, cloud and surface albedo, and visibility. In order to use the measured data, it will be essential to measure and record certain reference data including plane latitude and longitude, heading, airspeed, airplane attitude and airplane altitude. Time synchronization between various instruments will be provided through the incorporation of timing signals on the magnetic tapes used for recording the data. The magnetic tape format will be designed to permit direct data input into the ground data evaluating and computing system.

The manner in which the flight facility is integrated into the other efforts of the National Institute is of great importance. The object in having a flight facility is to provide university scientists with a modest but useful capability for making measurements and for carrying out experiments in the atmosphere. But the airplanes alone do not meet this objective. The airplane effort must lean heavily upon the Institute's instrument development group, the radar and electronics shops and the data analysis and computer facilities. In addition, the scientists using the airplanes need the opportunity for contact with the other scientific disciplines which will characterize the Institute, and the laboratory scientists will have need for occasional airplane support.

(2) Computer facility. One of the most important tools for atmospheric research to be developed in recent years is the high-speed, large-storage electronic computer. It finds great application in the solution of the mathematical equations describing physical processes in the atmosphere and in processing the incredibly large amounts of data collected in observational research programs. The need for computational facilities at the present time has almost outstripped the part-time availability of machines at those universities and research laboratories where such equipment are located.

There already exists a need for a computer devoted exclusively to basic research on atmospheric problems. With the expansion in atmospheric research, and the increasing sophistication of methodology, this need is going to increase substantially. It is already apparent that the reduction and analysis of data from meteorological satellites is going to impose even greater requirements for computational facilities.

To meet the needs of scientists at the universities and other meteorological research centers and to constitute an integral part of the research facilities at the Institute, it is essential that a computational laboratory equipped with a large-scale computer of the IBM 7090 or Philco Transac S-2000 class be available at the Institute. Problems that would require even larger computers were discussed at the research planning conferences. It was felt that arrangements to rent time on larger computers would be the best way to take care of these occasional requirements until the demand for this scale

of equipment is sufficiently great to justify purchase, construction or full-time rental of a larger machine.

(3) Library facility. A library of a high degree of excellence is universally accepted as a factor of major importance in setting the intellectual tone of a closely knit community of scientists. The desirability of a first-rate library in the atmospheric sciences at the Institute is supported by the fact that, in addition to serving the needs of the Institute staff, it would provide to the community of atmospheric scientists a greatly needed facility which is not generally available in this country.

A basic geophysical science library with back holdings of approximately 300,000 volumes and with a current acquisition rate of about 6000 books and 2000 serial titles each year is envisioned. Approximately 80% of the back holdings will be serial titles and the balance will be books. Approximately eight years will be required to bring the back holdings up to 300,000 volumes, but with a vigorous program of library build-up, and with proper selection, it should be possible to provide a useful library service at the end of two years.

(4) Radiation probing facility. An essential component of the complex of facilities needed at the Institute is a completely equipped station for probing the atmosphere by techniques which use one or more bands in the spectrum of electromagnetic radiation. The types of probing systems fall into four general classes: (1) microwave radar, (2) sferics, (3) optical radar (pulsed searchlight), and (4) infrared. In each of these classes, further development of equipment will be required to make it most suitable for atmospheric research, but it is considered to be desirable that this development work take place concurrently with the use of the equipment in an integrated research program. For example, advances in scattering theory will help to determine the direction in which the development of radar equipment should proceed. As new knowledge concerning atmospheric processes is acquired, new requirements for probing systems will arise. A major installation is planned for the Institute where its effectiveness will be enhanced by the close contact of the scientists engaged in experimental work with other scientists concerned with fundamental theoretical studies.

(5) Shop facilities. To provide proper support for experimental research and work in instrumentation, it is necessary to plan for both machine and electronics shops of about equal size and a complement of accessory shops capable of handling a variety of materials. From the number of scientists engaged in experimental work and from conventional ratios of scientists to skilled artisans, a shop staff of approximately fifty-four people is envisioned.

(6) The Institute building. The seventeen planning conferences held during the fall months of 1958 under the auspices of the University Committee for Atmospheric Research have provided a view of the research needs to be met by the Institute. Since this need is composed of many scientific parts and human relationships to be brought to fruition in one laboratory, it seemed necessary to visualize this laboratory and to prepare reasonably complete plans for a building. Both the specific requests for space and facilities, and the general requirements given during the course of the conferences have been translated by Dr. von Arx into designs consistent with the advice of men experienced in the construction and management of several well known university, government and industrial research laboratories. To this has been added thoughtful concern for the human service that the Institute structure must perform. Space does not permit a detailed discussion of these plans but the isometric drawing (Fig. 1) on an adjoining page will convey a general impression of what is envisioned. (The airplane is a mock-up for experimentation with installation of aircraft instrumentation.)

SCIENTIFIC MANPOWER AND BUDGET

In terms of the level of activity now regarded as necessary to make a material contribution to the atmospheric research effort and the diversity of talent needed to do so, it appears that approximately 108 research scientists may be required in the Institute. About one-half of these will have had training in the Earth sciences. In the remaining half, the three major disciplines of physics, mathematics and chemistry will be represented. This degree of diversity places a relatively light burden on the existing manpower resources in any one discipline. But since the number of pre-eminent men in any field is small the recruitment of first quality scientists

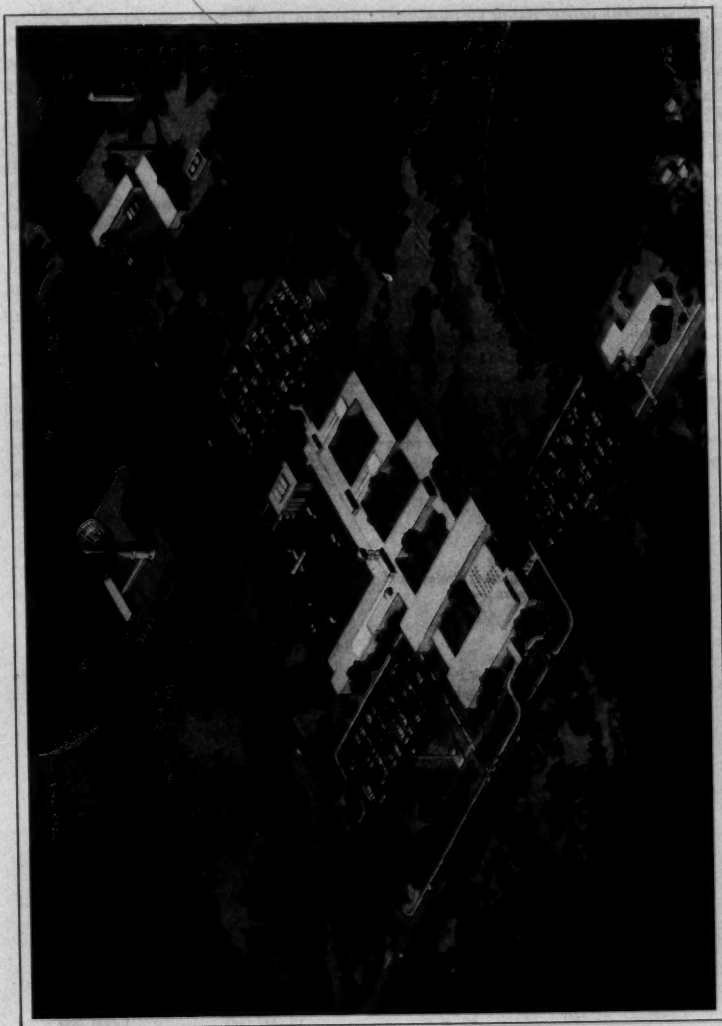


FIG. 1—Proposed layout of Institute for Atmospheric Research

must proceed with careful regard for excellence.

Approximately 54 scientists, including at least two scientists with marked creative ability from each of the major disciplines, will form the permanent staff of the Institute. An equal number of well-qualified visiting scientists will provide a total scientific staff of approximately 108. It is expected that about fifty of this total will be mature scientists. The remainder may be composed of research scientists of associate and some assistant grades so as to provide opportunities for younger post-doctoral and pre-doctoral students of many disciplines to become acquainted with atmospheric problems. A careful review of the scientific manpower require-

ments in terms of the scientists now available and to be available during the next few years indicates that the rate of staff acquisition given in Table 1 is not unrealistic.

In order to provide an estimate of the budgetary support that will be required, it has been necessary to project a schedule for the orderly establishment of the Institute. A summary of a detailed analysis of expenses is presented in Table 1. It is expected that it will be subject to modification as the Institute takes form. In particular, it will be very important that the acquisition of research facilities should not generate such pressure to obtain people that sacrifice in quality of staff might result.

TABLE 1—*Budget and manpower summary*

Fiscal year	Staff	Expenditures	
		Operating	Capital
1960	8 Scientists 8 Technical & Professional 5 Support people — 21	\$ 1,136,000	\$ 15,000
1961	25 Scientists 30 Technical & Professional 20 Support people — 75	2,350,000	14,240,000
1962	45 Scientists 70 Technical & Professional 40 Support people — 155	3,408,000	7,421,000
1963	65 Scientists 130 Technical & Professional 60 Support people — 255	6,380,000	7,927,000
1964	85 Scientists 200 Technical & Professional 150 Support people — 435	11,472,000	2,650,000
1965	108 Scientists 206 Technical & Professional 236 Support people — 550	13,296,000	1,000,000
	Total	\$38,042,000	\$33,253,000

CONCLUSION

It has been possible in this article to sketch only in broad outline the nature and the functions of the Institute as they have evolved during countless man hours of discussion among many groups during the past two years. Much more detailed information is available in the basic document⁴ from which practically all of the material in the present treatment has been drawn.

In a very real sense, however, the ultimate character of the Institute has yet to be determined. It will begin to take form only after a small group of scientists interested in the problems of the atmosphere assemble and form the

nucleus of the Institute staff. This, in turn, will happen only after mature and careful deliberation by the scientific statesmen who recommend policy to the executive and legislative branches of our government has led to the conclusion that the Institute will fulfill an important need in the nation's total scientific and educational effort. A strong indication that it will do just this is found in the forthright action by a substantial number of our great universities in recommending to the National Science Foundation that such an Institute should be established.

If a broad-gauged and far-sighted policy of support for basic research at the Institute, *and at the universities*, is forthcoming, the enthusiastic endorsement of the scientific community and the imaginative leadership by a group of our prominent universities provide ample assurance that a significant step forward can be taken toward solving one of the most difficult, but most important and most challenging, scientific problems of our times—a real understanding of man's atmospheric environment.

⁴Copies of the report "Preliminary Plans for a National Institute for Atmospheric Research" prepared for the National Science Foundation by the University Committee for Atmospheric Research can be obtained from Professor Henry G. Houghton, Chairman, UCAR, c/o Department of Meteorology, Massachusetts Institute of Technology, Cambridge 39, Mass.

The International Geophysical Year¹

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December 31, 1958 saw the end of the great enterprise of geophysical and solar observation known as the International Geophysical Year (IGY). As it began on July 1, 1957, the "Year" was of generous length, eighteen months. The scope of the enterprise was immense, and its success was remarkable. It engaged the co-operation of sixty-seven nations, of diverse race, color, religion, and political organization. All these joined freely and harmoniously together in the scientific study of the Earth and the Sun. It gave proof that however many and serious are the political problems that trouble the human race, it is possible for the nations to work together in a great enterprise planned for the common good. Thus by example it was an encouragement to peaceful cooperation also in other fields of activity. The simplicity of the essential purpose of the IGY made a strong appeal to the many governments throughout the world, and gained for it generous financial support. It received wide publicity by press, radio, and television, and caught the imagination of a considerable part of the general public. It led to scientific study and exploration of the Antarctic Continent on a scale beyond all previous endeavor. It opened a new era in the history of humanity, by stimulating the launching of earth satellites. This undoubtedly marked a notable step towards space travel, and a beginning of great new advances in the scientific study of the cosmos.

The observations made according to the IGY program by the various nations are to be pooled. They will be available for study by scientists of every country—whether or not their country took part in the IGY. Before the IGY began, agreement was reached on the establishment of at least three international repositories for the observations. These are called IGY World Data Centers. One is in the U. S.,

one in USSR, and other countries—Australia, Belgium, Denmark, France, German Federal Republic, Italy, Japan, The Netherlands, Sweden, Switzerland, and The United Kingdom—share in a third. The establishment and maintenance of these centers, working on agreed lines, represent an important contribution made by these nations to the IGY enterprise, additional to their own direct share in the observing program.

Each of the three centers will have a complete set of all the data, received either directly or by copying and interchange between the centers. The process of collection has been in progress during the IGY itself. It will be actively continued to completion during the present year. The organization of this work has been in charge of a special officer, the IGY Coordinator (Vice-Admiral Sir Archibald Day), since 1956.

The end of the period of IGY observations leads on to further vital phases of the enterprise. Besides the collection of the data in the World Centers, much of the material will be centrally published in summary form. Already before the IGY began, a new scientific journal of limited life was started, for publication of central IGY information. It is entitled *Annals of the International Geophysical Year* (or, briefly, *IGY Annals*). It is published by the Pergamon Press, under contract with the central IGY secretariat. The first four volumes (3 to 6) consisted of Instruction Manuals for various parts of the IGY program—to define what was to be done, and to ensure as much uniformity as possible in instruments and methods. Other volumes published or about to be published (1, 2, 7 to 10) give the history and planning of the IGY, the national programs, lists of IGY stations, and the report of the last IGY conference (Moscow, July-August, 1958) to consider the post-IGY phases of the enterprise. These ten volumes record the IGY phases that are now completed. Later volumes will give summaries of the re-

¹ Reprinted from *ICSU Review*, 1, 16-26, 1959.

² President, *ICSU Special Committee for the International Geophysical Year*.

sults, accounts of their analysis, interpretation and discussion, catalogs of the material available in the World Data Centers, and IGY bibliographies. From 1956 to May 1958 the *Annals* were in the charge of Sir H. Spencer Jones, as General Editor. Since May 1958 the *Annals* have been edited at the central IGY secretariat. Guidance on questions of publication was given to CSAGI by a committee presided over by G. Laclavère (1955-1956) and D. C. Martin (1956-1958).

During the present, and following years the International Unions that have been associated with the IGY will be organizing symposia on the results obtained in their various fields. Reports of these may be published in the *Annals*. Some countries will publish accounts and discussions of their own contributions to the observational work of the IGY. It is hoped that these will, where possible, be in a format similar to that of the *Annals*, and that the principal scientific libraries throughout the world will make available to their readers all the central and national IGY publications.

At the Moscow IGY Conference it was proposed by the USSR national committee for the IGY that the enterprise should be prolonged for a further year, until the end of 1959. The proposal found a number of supporters. However, representatives of some committees were unable to agree to it, because they had given definite assurances to their governments that the IGY enterprise would end with December 1958. Unanimous approval was given, however, to a resolution recommending a continuance of observations throughout 1959 according to the IGY program, to the greatest degree possible for each country. This successor enterprise was given the name International Geophysical Cooperation 1959 (IGC 1959). The central IGY secretariat and the office of the IGY Co-ordinator will continue until the end of October 1959. The central IGY organizing committee—known as CSAGI—will continue to the end of June 1959, to oversee until that date the later stages of the IGY enterprise and the first half of the IGC 1959. Then these functions will be transferred to a new and smaller body—known as SCG (Special Committee for Inter-Union Cooperation in Geophysics)—composed of some of the present members of CSAGI. But from the beginning of this year other new bodies

took over the responsibility for guiding and stimulating the continuance and extension of certain parts of the IGY program. These related to the antarctic, oceanography (biological as well as physical), space research, and the geophysical calendar giving days for enhanced observation. Some of these days, as in the IGY, are to be fixed beforehand; others are to be announced at short notice, when geophysical events occasioned by solar storminess seem likely to be imminent. The distribution of these notices will involve the continuance in some form of the IGY system of rapid collection of solar observations, their assessment (at a reception and analysis center) in relation to geophysical effects, and the rapid and extensive communication of the notices of special world intervals.

Another recommendation of the Moscow conference was that a new World Magnetic Survey be made—as a deferred but integral part of the IGY enterprise—within the next few years of diminishing solar activity. The IGY was organized in advance for the period 1957-1958, in the expectation that it would coincide with or include the maximum phase of the sunspot cycle—though advance prediction of the maximum epoch is not yet possible. The expectation as regards 1957-1958 was abundantly fulfilled. The daily sunspot numbers, which have long been used as an index of solar disturbance, attained abnormally high values on a surprising number of days. This made the IGY a period of many interesting solar and related terrestrial events, for whose study the enhanced activity of solar and geophysical observation in 1957-1958 will provide an exceptional amount of material. Such a period is less than normally suitable, however, for surveying the Earth's magnetic field. This can be done better during the coming few years of greater solar and magnetic calm. The detailed organization of the new World Magnetic Survey will be guided by the International Association for Geomagnetism and Aeronomy—part of the International Union of Geodesy and Geophysics.

Weather observations formed the largest single section of the IGY program. For many decades meteorological services have been part of the national government organization in most parts of the world. Since World War II these services have been linked under United Nations auspices in the World Meteorological

Organization (WMO). The WMO took a leading part in guiding and stimulating the IGY meteorological program, through its representatives on the central IGY organizing committee. It also undertook the function of data collection for meteorology. It organized the reproduction of all the IGY weather data on microcards—a big undertaking. Sets of these microcards are on sale at a cost of about \$6000, and they have been sold in numbers sufficient to cover the cost of reproduction. A set is available also for consultation at the US and USSR World Data Centers, but the sale of the sets, or of parts of them, will be made only through WMO. Important advances in meteorological knowledge may be confidently expected from the study of this enormous collection of data.

Before the IGY there were great gaps in the available weather data over the tropics and much of the southern hemisphere. These gaps presented a serious obstacle to the development of meteorological theory. The atmosphere is a complex dynamical fluid system on a spherical rotating Earth. The excess supply of heat in low latitudes activates a general circulation, transferring heat, momentum, and water vapor between different latitudes. The hydrodynamical and thermodynamic discussion of its motions, and of the changes of state of its water content, must inevitably be difficult. But given more adequate data, such as the IGY provided, there is hope that the difficulties can be at least partly overcome. Great assistance is now available from new computing machines of large capacity and high speed. The economic importance of weather and climatic prediction is such that it justifies considerable expenditure for skilled man-power and expensive equipment for the task. The IGY meteorological program was designed to further research into the most fundamental problems of atmospheric dynamics and thermodynamics. It is hoped also that much more will be learnt about the mutual influence of the atmosphere on opposite sides of the equator, and about the effect of the antarctic atmosphere on world weather. The intensified IGY observations of solar radiation and ozone will also contribute.

Incidentally the scientific expeditions to the antarctic have more than once during the IGY broken the world record for low air temperature

at ground level. To date this is now -86.7°C , as observed at the USSR station Sovietskaya ($78^{\circ} 24' \text{S}$, $87^{\circ} 35' \text{E}$; elevation about 12,000 ft) between 19h 00m and 20h 00m UT on August 9, 1958 (*Monthly Weather Review*, Washington, 86, 308, 1958). The low temperature record prior to the IGY, for a place in Northern Siberia, had stood since February 1933; it was -68°C .

Up to this point this account of the IGY has been concerned largely with the closing stages of the enterprise. Its scientific harvest will only gradually be reaped. But some mention can be made of a few striking results already obtained, such as the indication, just described, that the Antarctic Continent is the coldest region on the Earth. The arctic is warm by comparison—the ice cover over the Arctic Sea is an imperfect thermal insulator of the sea water below, whose temperature differs little from 0°C . As regards the land, the lowest temperature yet recorded in the Canadian arctic is -63°C , at Snag, Yukon, on February 3, 1947.

The many IGY expeditions to the antarctic made a substantial contribution to antarctic geography—by air and by traverse parties on land, of which the most notable was the British Commonwealth Transantarctic Expedition led by Sir Vivian Fuchs. Geographical progress was not among the stated purposes of the IGY, but in the antarctic, the only major region not yet fully explored, it was achieved incidentally. The IGY also made some incidental additions to biological knowledge. The primary objective of those who originally proposed and planned the IGY was the study of the geophysical aspects of the Earth that are most directly influenced by changes on the Sun. Hence glaciology was not initially on the IGY program. The world's ice coverage changes only slowly, and has no apparent connection with solar activity. But the presence of many expeditions on the Antarctic Continent made it expedient to study its snow and ice cover. Where this is deep the nature of the continent itself could not otherwise be known. Seismic methods revealed that in some regions the thickness of the ice is far more than had been supposed. For example, the US Byrd station, at 5000 ft above sea level, is found to rest on almost 10,000 ft of ice. The lower part of this ice may therefore be con-

sidered as a frozen sea or lake. This great weight of ice must somewhat depress the land bed there. Only by further seismic exploration will it be possible to map the sea-level contour over the antarctic. This will show whether the land there is mainly one continent, or a collection of islands. It will also improve the estimate of the world amount of water locked up in the solid form, as ice or snow, above sea level. The present uncertainty as to the exact amount is mainly due to ignorance of the average thickness of the antarctic ice. About one per cent of the Earth's water is in the form of glaciers, the largest fraction being antarctic.

While the ice of the antarctic was being studied, the glaciologists made a survey of glaciers in other parts of the world. Hence the area and volume of the glaciers will be fairly well determined during the IGY for the first time in the history of the science.

During the IGY the Sun was observed more fully and continuously than ever before. It seems likely that few if any important disturbances on the visible half of the Sun passed unobserved. The IGY sunspot maximum was notable for an unusual abundance of sunspots, rather than for groups of outstanding size, such as distinguished the previous maximum. The solar activity was associated with numerous great auroral, magnetic, and ionospheric disturbances. All these were observed with a degree of completeness beyond precedent. So also were the cosmic rays that penetrate the atmosphere: an extensive network of observatories registered cosmic ray meson- and neutron-secondaries; many special observations were made using balloons and rockets. The IGY did not include any cosmic-ray event approaching the importance of that of February 23, 1956. But by rockets and balloons the occurrence of penetrating radiations was observed, on some auroral occasions, down to no more than 20 miles above sea level. Other occasions of penetrating x-rays or protons were observed (August 1957, August 1958) in high latitudes, unaccompanied—surprisingly—by any notable aurora or magnetic disturbance.

Rockets explored the upper atmosphere—its pressure, temperature, density, composition, and electron and ion content. They studied the solar spectrum, notably during the eclipse of October 1958. The geomagnetic field above the Earth

was measured in auroral regions and also, by the U. S. 'moon rocket' of October 1958, far outside the earth (to a distance of over 80,000 miles).

The IGY satellites and the moon rockets provided one of the most outstanding discoveries during the IGY—namely two extensive belts of charged particles of considerable energy, trapped in the earth's outer magnetic field. Van Allen found that the first belt becomes prominent at 1400 miles height and extends to 3400 miles; the second begins at 8000 miles and goes to 12,000 miles.

Other important IGY results in many fields might be quoted, but limitations of space forbid. My final example is one that stems from recent advances in oceanographic techniques. The study of sub-surface oceanic currents has revealed the existence of a gigantic Pacific Ocean river, comparable with the Gulf Stream in dimensions and volume. Its length is at least 3500 miles, and its breadth 250 miles. It flows eastward at a depth between 100 and 800 ft below the surface, with a speed of about 25 miles per hour. Above and below it the water more slowly flows westward.

IGY ORGANIZATION

The story of the inception and development of the IGY enterprise is on record in numerous places; Volume 1 of the *IGY Annals* gives a rather full account of it, written by Sir Harold Spencer Jones. But it seems appropriate to include here at least a brief account of the IGY planning and organization.

The central organizing body was a Special Committee of the International Council of Scientific Unions (ICSU). The committee came to be generally referred to as CSAGI, a name formed from the initials of the title of the committee in French—Comité Spécial de l'Année Géophysique Internationale. (In many countries the IGY is referred to as AGI, Année Géophysique Internationale; in Russia the abbreviation is MGG). The stimulus for the appointment of such a committee naturally came from the international scientific unions concerned with the sciences of the Earth and Sun. Three unions have special concern in the IGY fields of observation. These are the International Union of Geodesy and Geophysics (IUGG), the Interna-

tional Astronomical Union (IAU), and the International Union of Scientific Radio (generally known as URSI, from its initials in French). The proposal that 1957-1958 should be a special year of geophysical and solar observation first came to these three unions through a joint commission appointed by them, under the sponsorship of ICSU. Its title is The Mixed Commission on the Ionosphere (MCI). Meeting in the summer of 1950, MCI considered the proposal to this effect, received jointly from two of its members—Lloyd V. Berkner, the prime initiator of the idea that 1957-1958 should be chosen for such an enterprise, and the writer of this article. The MCI welcomed the idea, elaborated the draft program we presented, and formally recommended to its parent unions that a third International Polar Year (IPY) should be organized in 1957-1958. What was intended was a second, extended, repetition of the first IPY of 1882-1883—which had first been renewed fifty years later, in 1932-1933. The two IPYs were periods of concentrated observation in high latitudes, chiefly in the arctic. In IPY, the subjects of study were weather (at ground level), geomagnetism, and aurora. In IPY, these were still the main objectives, but by 1932-1933 the weather was studied also up to a few miles height, by balloons equipped with recording instruments that transmitted their measurements to the ground by radio. In the IPY, also the arctic ionosphere was studied, by radio stations at ground level, for the first time. Lloyd Berkner proposed that a third IPY should be undertaken only twenty-five years after the IPY, because of the great advances in measuring techniques since 1933, and also because of the enhanced importance of radio communication and air travel.

Meeting in Washington in October 1951, the ICSU responded favorably to the proposals of the said unions that a third IPY should be organized for 1957-1958. On the initiative of Dr. von Murralt, then President of ICSU, it was decided to appoint a special committee to organize IPY. The statutes of ICSU recognized two kinds of committee: joint ones like MCI, and special committees. The latter kind was chosen because it allowed greater elasticity. The nucleus of the committee was appointed early in 1952, with E. Herbays as convener. Authorized by the committee, he invited the nation mem-

bers of ICSU, and also the USSR (not then a member), to take part in a third IPY. The response, though moderate, was encouraging. Later in 1952 the scope of the proposed enterprise was enlarged, and its name was changed to International Geophysical Year. New invitations to participate were issued.

The special committee, enlarged by ICSU partly as suggested by the members of the original IPY, committee, held its first full meeting at Brussels, June 30 to July 3, 1953. By that time 22 nations had agreed to take part in the IGY. Thirteen were represented at the meeting, and 13 sent proposals for the program. The first official IGY program was there drafted. It covered ten subjects, to which another four were later added.

The following list names the 67 countries whose committees took part in the IGY.

COUNTRIES THAT HAD COMMITTEES PARTICIPATING IN THE IGY

Argentina	Italy
Australia	Japan
Austria	Korea (Democratic
Belgium	People's Republic)
Bolivia	Malaya
Brazil	Mexico
Bulgaria	Mongolia
Burma	(People's Republic)
Canada	Morocco
Ceylon	Netherlands
Chile	New Zealand
Colombia	Norway
Cuba	Pakistan
Czechoslovakia	Panama
Denmark	Peru
Dominican Republic	Philippines
East Africa	Poland
Ecuador	Portugal
Egypt	Rhodesia and Nyassaland
Ethiopia	Rumania
Finland	Spain
France	Sweden
German Democratic	Switzerland
Republic	Taiwan
German Federal	Thailand
Republic	Tunisia
Ghana	Union of South Africa
Greece	USSR
Guatemala	United Kingdom
Hungary	U.S.A.
Iceland	Uruguay
India	Venezuela
Indonesia	Viet-Nam
Iran	(Democratic Republic
Ireland	Viet-Nam (Republic)
Israel	Yugoslavia

Three further planning meetings were held—at Rome in 1954, at Brussels again in 1955, and at Barcelona in 1956. Gradually the number of adhering nations grew. Among others, the USSR joined in 1954, and the Chinese People's Republic in 1955. To the great regret of CSAGI, the latter withdrew on the eve of the IGY, because the adherence of Taiwan had been accepted. Representatives of the IGY Committee of the Chinese People's Republic attended IGY meetings in 1956.

The CSAGI itself grew in numbers, to 24, as new unions or other bodies came to be represented on it. Fourteen of the members (called reporters) undertook special responsibility for the 14 branches of the IGY program. They presided over the working groups that elaborated the separate programs—with important aid from union and WMO and national IGY committees. They wrote or edited the instruction manuals, and will act as co-editors in their respective branches for the post-IGY publications in the *Annals*. The working groups in the different subjects did not have a continuing existence between CSAGI meetings. They were formed from the groups of national delegates present on each occasion. Below is given a list of the fourteen subjects of the IGY program, and of their respective reporters, together with their dates of appointment, and the names of the international bodies they represented in CSAGI. The list is followed by another giving similar particulars for the other ten members. Footnotes indicate other functions undertaken by the members.

IGY SUBJECTS: THEIR REPORTERS, WITH DATES OF APPOINTMENT, AND THE INTERNATIONAL BODIES THEY REPRESENTED ON CSAGI

- I. World Days and Communications, A. H. Shapley¹ (1956), URSI.
- II. Meteorology, J. van Mieghem (1953), WMO.
- III. Geomagnetism, V. Laursen^{1, 2} (1952), IUGG.
- IV. Aurora and Airlow, S. Chapman³ (1953), ICSU.
- V. Ionosphere, W. J. G. Beynon² (1952), URSI.
- VI. Solar Activity, Sir H. Spencer Jones (1953-6); Y. Öhman (1956-8), M. A. Ellison (1958), IAU.
- VII. Cosmic Rays, J. A. Simpson (1954), IUPAP (Pure and Applied Physics).
- VIII. Longitudes and Latitudes, A. Danjon (1953), IAU.
- IX. Glaciology, Sir J. M. Wordie³ (1952), IGU (Geography).

- X. Oceanography, G. Laclavère⁴ (1953), IUGG.
- XI. Rockets and Satellites, L. V. Berkner^{2, 3} (1952), ICSU.
- XII. Seismology, V. V. Belousov⁶ (1955), IUGG.
- XIII. Gravimetry, P. Lejay (1956-8), URSI; P. Tardi (1953), IUGG.
- XIV. Nuclear Radiation, M. Nicolet^{2, 7} (1952), ICSU.

¹ Member of CSAGI Finance Committee.

² Member of the original IPY, (later IGY) committee; this included also N. E. Nörlund and J. M. Stagg.

³ President of CSAGI.

⁴ Adjoint Secretary for Antarctic: Chairman, Publications Committee, 1955/6.

⁵ Vice President of CSAGI, 1953-1958.

⁶ Member of CSAGI Bureau, Vice President, 1959.

⁷ General Secretary of CSAGI.

CSAGI MEMBERS WHO WERE NOT REPORTERS
(ALPHABETICAL ORDER)

- M. Boella (1953), URSI.
A. F. Bruun (1955), IUBS (Biological Sciences).
J. Coulomb¹ (1952), IUGG.
E. Herbays² (1952), ICSU.
J. van der Mark (1956), CCIR (International Consultative Committee for Radio Communications).
H. E. Newell, Jr.¹ (1959).
B. van der Pol (1956), CCIR.
N. Pushkov (1955), IUGG.
T. E. W. Schumann³ (1953), WMO.
M. S. Vallarta (1954), IUPAP.

¹ Member of CSAGI Bureau.

² Convener of the original IPY, and IGY Committee; Chairman, CSAGI Finance Committee.

³ Adjoint Secretary, Africa S. of Sahara.

The executive body of CSAGI (called its Bureau), consisted until late 1956 of the three officers. Thereafter it was enlarged by the addition of two other members, indicated above. On January 1, 1959, H. E. Newell, Jr. succeeded L. V. Berkner as a member of the Bureau. In late 1956, also, ICSU formally defined the duties, responsibilities and powers of CSAGI. From 1955 onwards CSAGI was advised on non-scientific questions by an Advisory Council (ACIGY), composed at each meeting of the principal delegate of each IGY Participating Committee there represented.

Late in 1953, the CSAGI secretariat was established at Uccle, near Brussels. The Belgian government generously allowed the General Secretary to devote official time to his CSAGI duties. Since 1956 the central secretariat has

been accommodated in the Radiation Department (of which he is head) of the Belgian Royal Meteorological Institute. The central IGY organization was managed economically with only a small paid staff—namely five assistants working in the office of the General Secretary, and the General Editor and Co-ordinator, each with his own sub-office and a small staff.

To stimulate national adherences and to improve the IGY program in various regions of the globe, regional IGY meetings were held as follows—each organized with the aid of a regional Adjunct Secretary, here named:

Antarctic, G. Laclavère, Paris, 1955, 1956, 1957; Brussels, 1955.

Arctic, N. Herlofson, Stockholm, 1956.

W. Hemisphere, E. O. Hulburt, M. Maldonado-Koerdell, Rio de Janeiro, 1956.

E. Europe: J. D. Boulanger, Moscow, 1956.

Africa (S. of Sahara), T. E. W. Schumann, Bukavu, 1957.

W. Pacific, M. Hasegawa, Tokyo, 1957.

In addition, special conferences were held under the auspices of some of the CSAGI reporters to consider their individual parts of the IGY program. The largest of these meetings was that on Rockets and Satellites, held in Washington, September-October, 1957.

The central IGY expenses were met from three sources. In the early stages ICSU bore the main burden: in all (to the end of 1958) its contribution to the secretariat and for meetings and publications amounted approximately to \$40,000. Great support was given by Unesco, to a total of \$85,000 to the end of 1958; and it is giving further aid to the post-IGY phase of the enterprise. It has also valuably helped the IGY

in other ways. But from 1956 onwards, the main support came from the nations adhering to the IGY, which up to the end of 1958 had made the following contributions—to a grand total of over \$160,000. It is expected that for some time longer this aid will be continued for the central expenses of the IGY and the IGC 1959.

Up to the end of 1958 the total expenditure for the secretariat and for the meetings and publications of CSAGI amounted to approximately \$250,000. An early estimate (L. V. Berkner) of the total cost of the IGY enterprise was that it would be of the order of \$200,000,000. It now seems that including logistics the cost may have exceeded a billion. The central expenses amount on that basis to less than one tenth per cent.

Each nation paid for its own part in the IGY enterprise, apart from a number of cases of mutual help as regards funds or equipment. Of course, their contributions to the work ranged widely in scope and scale. One of the most costly parts of the program was that relating to the antarctic. Twelve nations—Argentina, Australia, Belgium, Chile, France, Japan, New Zealand, Norway, Union of South Africa, USSR, UK, and US—sent expeditions to the continent and islands.

Another very expensive part of the program was the launching of rockets and satellites for the scientific study of the upper atmosphere and the space beyond. Rocket researches were included in the US-IGY program from the outset. After the USSR joined the IGY in 1954, they also included such researches in their program. Australia, Canada, France, Japan, and UK did likewise, on a smaller scale. Satellite launching for IGY purposes was tentatively proposed in 1954. In 1955 the US announced its intention to put IGY satellites in orbit, and made extensive plans for the associated scientific equipment and experiments. The USSR in 1956 announced its intention to launch satellites, and was the first to achieve success, in October 1957. Many IGY countries took part in the tracking and the reception of the signals of these satellites.

An outstandingly original and important allied research became associated with the USA IGY program during the course of the IGY itself. It was called the Argus project, and consisted in

CONTRIBUTIONS TO THE CENTRAL IGY EXPENSES
BY THE ADHERING NATIONS (TO THE END OF 1958)

Australia	\$ 2,000	Morocco	\$ 500
Canada	10,000	New Zealand	700
Czechoslovakia	500	Rhodesia &	
Denmark	500	Nyasaland	500
France	2,381	Sweden	500
Guatemala	500	Tunisia	500
Indonesia	500	USSR	45,000
Israel	500	U. of S. Africa	500
Italy	1,000	U.K.	21,000
Japan	3,000	U.S.A.	75,000
Mexico	500	Yugoslavia	500
TOTAL			\$ 166,081

the creation of artificial radiation regions high in the Earth's atmosphere, by the explosion of small nuclear bombs at a nominal altitude of about 300 mi, in August (27 and 30) and September (3), 1958. Within a minute of the explosions artificial auroras appeared, and radio communication was affected over a considerable area. These events mark the beginning of *experimental* as distinct from purely observational research into solar effects on the atmosphere and the environment of the Earth—a most remarkable and unexpected development.

Tens of thousands of scientists and their assistants took part in the IGY enterprise. For some it involved hardship and danger. For all it has meant extra effort, in their personal scientific work, on committees, and as authors and correspondents.

Presiding over the International Union of Geodesy and Geophysics at Toronto in Septem-

ber 1957, K. R. Ramanathan referred to the IGY as follows.

"The ICSU and the CSAGI have done a great job. The greatest single achievement of organized science in history was perhaps the building of the first atom bomb. It required the bringing together of many top-ranking scientists, technologists, and organizers on an unprecedented scale. But they were top-ranking men, and of a few countries only. The IGY is in my view an undertaking of greater magnitude and difficulty, because it has involved the bringing together of workers of many nations with differing ideologies and in very varying stages of scientific development. A keen, diligent observer with modest education in any corner of the world has a respected place in the IGY scheme. The approach is human and earthy, and the potentialities for the unification of mankind are infinitely greater."

Earth Science Center at Massachusetts Institute of Technology

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An integrated and unified instructional and research program in the earth sciences is being organized at MIT. Included in this effort are geology, geochemistry and geophysics, the atmospheric sciences, and the oceanographic sciences. Space, facilities, staff and students will be brought together in a common educational effort.

Space and facilities—A recent gift of \$2,527,500 from Mr. and Mrs. Cecil H. Green of Dallas, Texas (Mr. Green is Chairman of the Board of Geophysical Service, Inc. and a Vice President of Texas Instruments, Inc.) will be used to create a Center for Earth Sciences in the form of a major building on the MIT campus. This building will house the teaching and research facilities and laboratories to be used in the program and will be the center for most of the activities in the several Earth sciences.

Funds are being sought to provide the most modern equipment and facilities to go into the new building and to support the instructional and research activities of the Center. The existing Earth sciences program has the use of the nuclear reactor and the IBM 704 digital computer, as well as a large number of other major facilities at MIT, and cooperative arrangements with the Woods Hole Oceanographic Institution make it possible for MIT staff members and graduate students to carry on research there and on their ships at sea. It is planned to diversify and improve existing facilities further and to cooperate even more closely with Woods Hole once the Center is in full operation.

Staff—The Center's instructional and research program will be conducted by staff members of MIT's present departments of Geology and Geophysics, and of Meteorology, joined by professors from other MIT departments and scientists from the Woods Hole Oceanographic Institution. Five of the latter will hold joint appointments at Woods Hole and MIT and will participate on a part-time basis in the Center's

instructional program at MIT. They will also supervise student research work at Woods Hole. These are Columbus O'D. Iselin, Willem V. R. Malkus, Henry Stommel, and William S. von Arx, all Professors of Oceanography, and J. Brackett Hersey, Associate Professor of Oceanography.

Students and program—Figure 1 is a flow-sheet illustrating how students will carry on

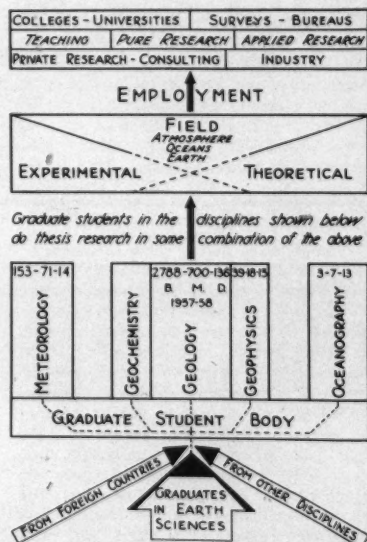


Fig. 1—A flow-sheet of graduate education as planned for the Center for Earth Sciences at MIT; the numbers in the middle of the diagram refer to the different degrees awarded in 1957-1958 in the several sciences, with the few in geochemistry included in geology; B—Bachelors; M—Masters; D—Doctors

graduate work in the earth sciences at the Center. All students will have in common a thorough preparation in mathematics, physics, and chemistry as a foundation on which to build their graduate work. Incoming graduates from other institutions will be given full opportunity to strengthen their preparation in the basic physical sciences, if that is necessary, while carrying on advanced work in the field of their special interest.

Graduates in mathematics, physics, and chemistry, in chemical, civil, and electrical engineering, and in the several Earth sciences will be encouraged to prepare themselves in one of the major Earth sciences shown on the diagram. Places and types of employment for which such students would be prepared are indicated at the top of the figure.

Shown on Figure 1, and tabulated below, are the most recent data available on the numbers of different degrees awarded in the several Earth sciences. These numbers, which are for 1957-1958, show the low productivity in all of the Earth sciences except geology and indicate the fields in which educational effort must be greatly increased.

Field	Bachelors	Masters	Doctors	Total
Geology	2788	700	136	3624
Geochemistry	(The few degrees awarded are included in Geology)			
Geophysics	39	18	15	72
Meteorology	153	71	14	238
Oceanography	3	7	13	23

Undergraduate work in both geochemistry and geophysics is increasing, so that the future should bring some increase in the numbers of different degrees in each of these sciences.

The recent report of the University Committee on Atmospheric Research (February, 1959) finds "... the output of meteorologists from the universities inadequate to meet even the static needs of the science," and emphasizes the need for many more able and well-trained students in this field. One of the major efforts of the Center will be to find and train such students for professional careers in the atmospheric sciences.

The report in progress by the Committee on Oceanography of the National Academy of Sciences—National Research Council stresses in its first chapter (Introduction and Summary of

Recommendations, published in March, 1959) the growing need for detailed knowledge and understanding of the oceans and their contents, and recommends, among other things, (1) that universities increase the numbers and quality of their output of oceanographers, and (2) that institutions primarily concerned with oceanographic research develop "... close formal affiliations with universities." MIT and Woods Hole have taken several long steps forward in carrying out these two specific recommendations, and the future activities of the Center will almost certainly bring the two institutions even closer together.

Although there does not seem to be any major committee now looking into the whole matter of the study of the solid Earth, as has been the case with the atmosphere and the oceans, nevertheless, there have been several recent and important reports that have pointed out the national need for continued and intensified efforts to understand better our physical environment and our earth materials. Two of these may be mentioned: (1) A Report to the President by The President's Materials Policy Commission, published in June, 1952, and (2) Report of the Advisory Committee on Minerals Research to the National Science Foundation, published in 1956. These reports stress the great need for broadening and deepening knowledge and understanding of our raw materials and natural resources and for developing new methods and techniques that can be used in extending this knowledge and understanding.

On February 1, 2 and 3, 1956, a conference on theoretical geophysics was held at the National Science Foundation in Washington, D. C., for the purpose "... of obtaining a broad picture of the current status of knowledge of geophysics, and especially of that gained mainly by theoretical geophysics in this country and abroad, to encourage increased activity in theoretical geophysics, and to discuss future programs and opportunities." This important conference, attended by more than one hundred invited participants, is reported in the *Journal of Geophysical Research* [6x, 317-414, 1956].

A major part of the Center's program will concern itself with training geologists, geochemists, and geophysicists for teaching, for research assignments, and for professional careers in applied science. It is hoped that these scientists

will help to meet the needs pointed out in the aforementioned reports.

In summary, the overall program of the Center will attempt to integrate and unify instruction and research in such a way that any graduate with good training in mathematics, physics, and chemistry, and training or an interest in Earth science, can proceed to graduate work with many choices as to the field or fields in which he can train himself. Its primary purpose will be to gain a better understanding of our physical environment of land, sea, and air, and to train students competent to go forth and continue some aspect of this program elsewhere. Thus teaching and research, which are considered inseparable, will strengthen and supplement one another.

Training of students—As mentioned earlier, graduates in any of the physical or Earth sciences will be encouraged to enter some phase of the Center's program. Once the graduate student has met all of the requirements for doing thesis work, he then chooses some problem for investigation and commences his research (Fig. 1). If he wishes to do a theoretical thesis, he will be invited to work with a closely cooperating group of mathematicians, physicists, geophysicists, meteorologists, and oceanographers, certain of whom will guide him in his research. A student wishing to do an experimental thesis will join some research group in the Laboratory of Earth Sciences, where he will find up-to-date equipment and facilities and where his actual work will be supervised by experienced staff members. Students interested in doing outside field work will be encouraged to use the facilities of Woods Hole for oceanographic research, those of the MIT Department of Meteorology for atmospheric research, and those of the Department of Geology and Geophysics for geological, geophysical, and geochemical work.

As indicated by broken lines near the top of Figure 1, a thesis problem is likely to involve work in more than one of the three research areas, and it is envisioned that all three types of research—*theoretical, experimental and observational*—will go on simultaneously in our Laboratory of Earth Sciences, which will constitute one of the major parts of the Center.

Thesis research in interdepartmental and interdisciplinary fields is already quite common at MIT and will continue to be encouraged for students judged competent to work in more than one field.

Students now registered for graduate work may earn advanced degrees in any of the major Earth sciences. A guidance committee is organized for each degree candidate, and the members of this committee work closely with the student.

Summary—The instructional and research program of the proposed Center for Earth Sciences at MIT is expected to produce well-grounded physical scientists with some knowledge of each of the principal Earth sciences and considerable knowledge of at least one of these. It is hoped that some of these graduates will accept teaching and research positions and thus spread the philosophy that future Earth scientists should base their training and research on a strong foundation of mathematics, physics and chemistry, supplemented by extensive field work whenever possible.

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Reviews

ALBERT DEFANT AND FRIEDRICH DEFANT, *Physikalische Dynamik der Atmosphäre (Physical Dynamics of the Atmosphere)*, Akademische Verlagsgesellschaft, Frankfurt a.M., 527 pp., 139 figs., 1958.

The two authors, a father and son team, set themselves the formidable task of creating a rounded picture of atmospheric dynamics as it appears to the contemporaneous meteorologist. They have succeeded in presenting an eminently readable textbook of theoretical meteorology, with just enough reference to the actual atmospheric events and observations to hold a student's interest.

The basic concepts are systematically developed and are clearly defined and explained. There is a welcome chapter on radiation, a subject often glossed over too lightly in other books on atmospheric dynamics. One must raise an eyebrow though in this space age if doubt is expressed at measuring the solar constant extraterrestrially. Also meritorious is the chapter on turbulence and mass exchange. This is followed by an able discussion on friction and turbulence with primary reference to local circulations. In this it follows the well-known papers of the junior author. Equally well treated are the evaporation problems.

By far the largest chapter, 175 pages in length, is devoted to the general circulation in the atmosphere and its disturbances (deliberately leaving out meso-scale phenomena and tropical storms). The development of the theory is clearly traced from Jeffreys and Exner to Bjerknes and to the Rossby-Petterssen-Palmén concepts of recent years.

This is followed by a very brief introduction to numerical prediction, which is left at about the 1955 state of the art. In such a rapidly developing branch it is hard to keep textbooks abreast of the latest developments. A final chapter deals with tide-like phenomena in the atmosphere.

Each chapter is accompanied by a fairly extensive bibliography. One is pleased to see adequate references to the pioneering efforts in the field. In particular, Margules gets the credit he deserves. Among the modern writers one misses Queney. Incidentally, in a second edition the various misspelled names (Jacobs, Nikuradse, Pierson, Jr.) might be corrected.

In leafing through this contribution one becomes aware how narrow the numerical base of autochthon, that is, American schooled, theoretical meteorologists, still is, a deficiency which our universities should remedy. It is also painful to note the gap that exists between the theoretical developments and the application in the day-to-day practice of meteorology.

H. E. Landsberg

R. C. SUTCLIFFE (ed.), *Proceedings of the Polar Atmosphere Symposium*, part I (Meteorology Section), Special supplement to *Journal of Atmospheric and Terrestrial Physics*, Pergamon Press, 341 pp., 1957, \$12.00.

The Polar Atmosphere Symposium, held at Oslo, July 2-8, 1956, brought together meteorologists from Norway, Sweden, United Kingdom, Germany, Canada, and the United States who have been engaged in research on problems of the polar atmosphere. Twenty-three papers were presented; 21 of these are included in the volume reviewed here; in addition, introductory remarks and four periods of discussion have been published in detail. The topics covered by the papers include in order: reviews of polar geography, climate and research efforts, the general circulation of the troposphere, the arctic stratosphere, the maintenance of anticyclonic circulation, cold-air poles and stratospheric high pressure centers, forecasting problems, weather analysis, representation of the pressure field, radiation measurements, heat transfer at the surface, the 'arctic whiteout,' ozone relationships, visual range, observational problems, surface inversions, problems of sea-ice distribution.

The best thing that can be said about this volume is that it demonstrates that there exists under the label *polar meteorology*, no substantial body of special scientific knowledge; anyone who needs this evidence now can have it at a cost of \$12.00.

Little organization of the problems was evident in the program of the Symposium and little more emerges clearly from the published report. Nevertheless, it is convenient to distinguish three main groups of papers: (1) those which used data collected in polar regions to extend our knowledge of fundamental problems, (2) those concerned with specific practical problems of polar transportation, and (3) recitals of the course of rather un-inspired polar research programs. Only a few of the papers are concerned with problems which have been formulated in proper scientific terms; these deserve publication in a scientific journal of first rank; the remainder should never have been granted the immortality of the printed page. No 'bold new ideas' were revealed at the Symposium; and when one of the speakers pleaded for a fresh look at frontal concepts, he was widely misunderstood by the assembled scientists.

Publication of this volume raises the question of the validity and wisdom of fencing off a part of meteorology under the label *polar meteorology*. No justification can be found for this in the general circulation, for both observation and theory indicate that the large-scale circulation of middle and high latitude functions as a complex, interacting unit. Conceivably, the distinction might be

justified if the relevant meteorological problems were so highly developed that one could isolate particular aspects for intensive study. But the message of this volume is the exact opposite—the relevant problems in polar regions, as elsewhere, remain the description and understanding of the large-scale structure and behavior of the whole atmosphere, and the physics of energy transfer. And those concerned with specialized problems of polar regions need more than anything else the stimulation of broadly trained imaginative minds occupied with more general problems.

R. G. Fleagle

K. WEEKES (ed.), *Proceedings of the Polar Atmosphere Symposium*, part II (Ionospheric Section), Special supplement to *Journal of Atmospheric and Terrestrial Physics*, Pergamon Press, 212 pp., 1957, \$10.50.

This book is comprised of the 21 papers, including discussions, presented at a Symposium under the same title in Oslo, Norway, during July 1956. As such it is, in effect, a report on one of the activities of the Advisory Group for Aeronautical

Research and Development of NATO for whom it was prepared as AGARDograph no. 29, part II.

The papers, and ensuing discussions, are divided into three sections. The first of these is primarily concerned with the dynamics of the ionosphere involving drift movements and irregularities, with some emphasis on higher latitude observations. In particular, much of the work on drifts subsequent to the summary paper of Briggs and Spencer (Rep. Prog. Phys. 1954) is considered. The second section is comprised of papers dealing with high-latitude ionosphere propagation prediction techniques and polar ionospheric disturbances. It is an excellent summarization of current knowledge in these fields. The final grouping of papers deals with turbulence theory, E_s, and ionospheric scatter propagation; the latter again with emphasis on polar regions.

In general, the papers range from summaries to original contributions in the fields of interest to the symposium. Consequently, this book is recommended for the library of any serious group of workers in this field.

A. H. Waynick

Contents of Bulletin (Izvestiya), Academy of Sciences, U.S.S.R. Geophysics Series, October-December, 1957

Note—The March issue of the *Transactions* (pp. 28-31) listed the contents of *Izvestiya*, Geophysics Series, for the interval January to September, 1957. Subsequent issues will carry information concerning the contents for 1958. The production of the English edition of *Izvestiya* for 1957 was undertaken on behalf of the American Geophysical Union by Pergamon Press with the aid of a grant from the National Science Foundation. Orders for sets (\$25.00 plus a service charge of \$3.00) should be sent to the American Geophysical Union. The production of the 12 numbers issued in 1958 is being undertaken directly by the American Geophysical Union. Subscriptions for the volume, the numbers to be sent as issued, are \$25.00.

No. 10, October 1957

TERRESTRIAL PHYSICS

Reflected and head waves emerging at a plane interface of two elastic media—I, N. V. Zvolinskii, 21 pp.

Certain interference phenomena in a two-layer medium, G. I. Petrashen', 15 pp.

MARINE PHYSICS

Theory of transient wind currents in an isotropic ocean, A. S. Sarkisyan, 7 pp.

ATMOSPHERIC PHYSICS

A theory of slope winds, L. N. Gutman and T. D. Koronatova, 13 pp.

Research on the solar constant, P. A. Krylov, 16 pp.

REPORTS AND NOTES

A study of the character of diminution of amplitudes of waves in the shadow zone of the Earth model, L. N. Rykunov, 5 pp.

The accuracy of determination of depths of disturbing masses, using as an example the magnetic anomalies of Bashkiria, V. M. Devitsyn and M. I. Lapina, 7 pp.

CURRENT EVENTS

Conference on the problems of investigating thunderstorm and hail-storm phenomena in the Alazan valley, 1 p.

Conference of the Main Geophysics Observatory on the meteorology of the surface air layer, 2 pp.

No. 11, November 1957

Soviet geophysics and the fortieth anniversary of the Great October Socialist Revolution, 10 pp.

Origin and composition of the Earth, B. Yu. Levin, 10 pp.

Forty years of seismology and seismic service in the U.S.S.R., E. F. Savarevskii, 10 pp.

The development of ultrasonic methods in seismology, Yu. V. Rizmichenko, 7 pp.

Development of seismic prospecting in the Soviet Union, I. S. Berzon, 13 pp.

- Electro-geophysical prospecting in the USSR., A. I. Zaborovskii, 7 pp.
 Forty years of Soviet ocean physics, V. V. Shuleikin, 20 pp.
 The work of Soviet geophysicists on problems of dry-land hydrology, M. A. Velikanov, 5 pp.
 Soviet studies in the field of atmospheric turbulence, A. M. Obukhov, 5 pp.
 Investigation of the high layers of the atmosphere, V. V. Mikhnevich and I. A. Khvostikov, 20 pp.
 The work of Soviet scientists on the night airglow and the polar aurorae, B. A. Bagaryatskii, 9 pp.
 A concise outline of current concepts of radio wave propagation and the ionosphere, Ya. L. Al'pert, 14 pp.

No. 12, December 1957

TERRESTRIAL PHYSICS

- Some new methods of seismological investigation, G. A. Gamburtsev, 8 pp.
 The correlation of seismic waves in seismic depth soundings of the Earth's crust, P. S. Veitsman, 20 pp.
 Seismological work in Japan, E. F. Savarenskii, 18 pp.
 The organization of the network of magnetic observatories in the USSR. during the last 40 years, Yu. D. Kalinin, 10 pp.

MARINE PHYSICS

- Temperature oscillations in the surface layer of the sea caused by wave movement, G. E. Kononova and N. V. Kontoboitseva, 7 pp.

ATMOSPHERIC PHYSICS

- Spectral composition of γ -radiation of elements of

- the uranium and thorium series, T. I. Sisigina, 9 pp.
 The spectral indicatrices of large water drops and the spectral polarization of rainbows, K. S. Shifrin and Yu. I. Rabinovich, 17 pp.

REPORTS AND NOTES

- Earthquakes in central Yakutia, P. A. Solov'ev, 5 pp.
 Destructive earthquakes in the Transcaucasus and the phases of the Moon, G. P. Tamrazyan, 3 pp.
 The interpretation of the anomalies of Δg by the direct method, E. G. Bulakh, 4 pp.
 Method of interpreting curves for electromagnetic soundings, B. S. Enenashstein, 7 pp.
 Centers of action in the atmosphere, Sh. A. Muselyan, 5 pp.
 Resistance of an unoriented body in motion in a rarefied gas, M. L. Lidov, 6 pp.
 Analyser for cloud and rain particles, A. E. Mikirov, 4 pp.

CURRENT AFFAIRS

THESES AND DISSERTATIONS

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 The piezoelectric effect in rocks, E. I. Parkhomenko, 1 p.
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English Translations of Russian Scientific Journals and Papers

Many more translations of Russian scientific writings are available than is generally realized. In order to indicate what is available, the Office of Technical Services of the U. S. Department of Commerce has begun a semi-monthly publication entitled *Technical Translations* which lists translations not only from the Russian but from other languages as well available through various organizations in the United States, Canada, Great Britain, and Australia. Some of these are translations in full; others are abstracts of papers in journals, as indicated below. The following information is taken from the first six numbers of *Technical Translations*, giving information bearing on subjects that are likely to be of special interest to geophysicists. The initials indicate sources from which translations may be obtained as follows: ATS, Associated Technical Services, Inc., P. O. Box 271, East Orange, New Jersey; CB, Consultants Bureau, Inc., 227 West 17th Street, New York 11, New York; LC, Photoduplication Service, Li-

brary of Congress, Washington 25, D. C.; MDF, Morris D. Friedman, Inc., Foreign Technical Translations, 67 Reservoir Street, Needham Heights 94, Massachusetts; OTS, Office of Technical Services, Department of Commerce, Washington 25, D. C.; SLA, SLA Translation Center, The John Crerar Library, 86 Randolph Street, Chicago 1, Illinois; mi, microfilm; ph, photostat.

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Notes and Personalia

Notes

COMMITTEE ON ATMOSPHERIC SCIENCES—The Committee on Atmospheric Sciences of the National Academy of Sciences—National Research Council, originally set up under the Chairmanship of Lloyd V. Berkner, is now under the Chairmanship of Paul E. Klopsteg. The report of the Committee included recommendations for the establishment of a National Institute of Atmospheric Research.

Another committee on which 13 universities offering extensive courses in meteorology are represented has taken steps to organize with the establishment of the National Institute. The following universities are represented on the committee: University of Arizona, University of California, University of Chicago, Cornell University, Florida State University, Johns Hopkins University, Massachusetts Institute of Technology, University of Michigan, New York University, Pennsylvania State University, St. Louis University, A and M College of Texas, University of Washington, and University of Wisconsin. The Alfred P. Sloan Foundation has granted \$45,000 to this university committee for its studies and for fellowships.

The National Science Foundation has likewise created a Program for Atmospheric Sciences under the direction of Earl G. Droessler. This office is interested in receiving applications for grants to further research in the atmospheric sciences. Grant communications should be addressed to the National Science Foundation.

For fiscal year 1959, a program of \$1,130,000 has been set up which will cover thirteen grants for laboratory research, field experiments, evaluation of present theory and practices, and conferences on meteorological methods directed toward weather modification. Included in this is AGU's Conference on the Physics of Precipitation, to be held at Woods Hole Oceanographic Institution, June 3-5, 1959.

NEW ANTARCTIC RESEARCH PROGRAM INITIATED BY THE NATIONAL SCIENCE FOUNDATION—The National Science Foundation has established an Antarctic Research Program, with Thomas O. Jones as the Program Director. The Foundation

has designated Albert P. Crary as Chief Scientist of the program.

Following the close of the International Geophysical Year it was determined that additional scientific programs should be undertaken in the Polar regions by the United States and should be budgeted and coordinated through the National Science Foundation. The Foundation will look to the Committee on Polar Research of the National Academy of Sciences for recommendations regarding the desirability of proposed programs. The Antarctic Research Program of the National Science Foundation has been established to coordinate the scientific efforts of the several Federal agencies that have an interest in Antarctic research and to receive proposals from universities and independent investigators for such research. Suggestions and proposals should be sent to the Antarctic Research Program, c/o National Science Foundation, Washington 25, D. C.

NEW CENTER FOR EARTH SCIENCES TO BE ESTABLISHED AT MIT—Cecil H. Green, alumnus of MIT and Chairman of Geophysical Service, Inc., and Vice President of Texas Instruments, and Mrs. Green have made a gift of 30,000 shares of stock of Texas Instruments (current value, over \$2½ million) to Massachusetts Institute of Technology for the construction of a major building to house the laboratories and other facilities as a center for Earth sciences, emphasizing the various aspects of geophysics. Further word will be carried concerning this matter when details are developed and available.

NEW STRATIGRAPHIC FIND IN THE PACIFIC—A layer of clean white ash which is believed to record a momentous event in the Earth's history has been discovered in the bed of the Pacific Ocean by Columbia University scientists. Until the age of this fine-grained ash of glassy fragments and its extent and identification are determined, it can only be speculated whether this was caused by volcanic action, a collision of heavenly bodies in outer space, or some other event. The ash was discovered over a large area of the tropical eastern

Pacific, extending 750 mi north of the Equator and 825 mi south of the Equator, and within a few hundred miles of Central and South America. It ranges in thickness from an inch to a foot. In some areas the layer rises to the ocean floor, and in others it is as deep as 120 ft below the ocean bed. In the area where this was found the ocean ranges in depth from a little less than a mile to over three miles. There are indications that the ash covers a much larger area and that it was probably deposited within the last 100,000 years. Inasmuch as it is not discolored and contains nothing but glassy ash material, it must have been laid down fairly quickly. A more detailed report is found in a recent issue of the *Proceedings of the National Academy of Sciences* by J. Lamar Worzel.

LOCATION OF MOUNTAIN RANGE ESTABLISHED IN ANTARCTIC—A mountain range whose existence has been an enigma for 20 years has been positively located by a team on a three-week trek completed in March 1959 in connection with the U. S. Antarctic Research Program. The range, called the Executive Committee Range, is located in the heart of Marie Byrd Land. Its existence had previously been reported by flyers on two earlier Antarctic expeditions. The ten peaks of the range are from 7144 to 13,856 ft high and extend north and south for about 60 mi between 76° 20' S and 77° 20' S. Preliminary investigations indicate that the mountains are volcanic in origin and about 90 pct covered with snow and glaciers.

SPACE SCIENCE PROJECTS—Homer E. Newell, Jr., Assistant Director for Space Sciences of the National Aeronautics and Space Administration, has outlined the following procedure for the submission of scientific project proposals and research ideas.

Prior to the preparation of formal project proposals, it will frequently be helpful for the individual investigator to become fully cognizant of the technological capabilities of available and planned space vehicles, such as rockets, satellites, and space probes. To this effect, the NASA Office of Space Sciences welcomes the initial receipt of informal project ideas and, upon preliminary evaluation, will provide the pertinent information and assist in correlating scientific objectives with payload and system capacities.

As individual experiments and proposals are approved and become part of the national space program, NASA Space Sciences Working Groups are set up to ensure that the project is carried out rapidly and effectively. Members on such Working Groups include the scientists and engineers who are preparing the scientific experiments for the project as well as others who participate and help in the construction and testing of the experimental equipment and payload packages.

CLOUD COVER SATELLITE—A 20-inch spherical satellite was launched at Cape Canaveral on Febru-

ary 17, 1959, under Project Vanguard, this satellite being especially designed to give information on the Earth's cloud cover. This was put in an orbit at altitudes ranging from a little over 900 miles to over 2000 miles. Weighing only slightly over 20 pounds, this sphere carried two transmitters, a receiver, a recorder, batteries, and photocells. As the satellite's photocells sweeps through the sunlit side of the Earth, the intensity of light reflected through cloud areas is much greater than that reflected from land or sea areas. This difference in light intensity is transmitted to the Earth to give the desired information on cloud cover.

SYMPOSIUM ON GEOCHEMISTRY TO BE HELD IN GERMANY—A Symposium on Geochemistry organized by the Commission on Geochemistry of the International Union of Pure and Applied Chemistry will be held August 21-22, 1959, to be followed by two days of field excursions. Topics for discussion at the Symposium are: (1) Stable nuclides in geochemistry, (2) Long-lived radio-nuclides in natural systems, (3) Geochemistry of the halogens, and (4) Geochemical aspects of life on Earth. The excursions will be to the Harz Mountains and the Zechstein salt deposits along the Werra. Interested persons should get into touch with the local Chairman, Professor C. W. Correns, Sedimentpetrographisches Institut, Lotzestrasse 13, Göttingen, Germany.

SYMPOSIUM ON GEOCHEMISTRY IN RELATION TO VOLCANOLOGY—The International Association of Volcanology of the IUGG will hold a Symposium in Paris, September 15-19, 1959, bearing on the following subjects: (1) Geophysical and geochemical survey of active volcanoes and the possibilities of predicting and controlling eruptions; (2) Elaboration of recommendations for emergencies relating to the safety of inhabitants, the delimitation of danger zones, and collaboration with civil and military authorities; and (3) Utilization of volcanic energy. Persons interested in this Symposium should get into touch with the local Chairman, Prof. B. Gèze, Institut National Agronomique, 16 rue Claude Bernard, Paris 5e, France, or with the Secretary of the Association, Professor F. Signore, Via Tasso 199, Napoli, Italy.

NEW PHOTOMETER FOR MEASURING AEROSOL CONCENTRATION—A new portable aerosol photometer has been developed by Southern Research Institute weighing only ten pounds and occupying about a cubic foot of space for counting aerosol concentrations up to 200,000 particles per liter and with special dilution attachment up to 2 million particles per liter. It can detect particles as small as 0.3 micron in diameter. It operates on a battery and can operate continuously for as long as four hours.

REPORT OF THE COMMITTEE ON OCEANOGRAPHY OF THE NATIONAL ACADEMY OF SCIENCES—NATIONAL

RESEARCH COUNCIL—This Committee was established by the National Academy at the request of the U. S. Atomic Energy Commission, the Bureau of Commercial Fisheries, the National Science Foundation, and the Office of Naval Research. Under the Chairmanship of Harrison Brown, the Committee was formed to consider ways and means of more extensive development of oceanographic research including phases not of military interest and has prepared a ten-year program which it contemplates will cost about two-thirds of a billion dollars. The program contemplates at least doubling basic research activity during this interval, covering all the oceans of the Earth, and developing a much fuller realization of the sea's resources and potentialities. The great need is for research vessels and the development of competent personnel. It is noted that there are 45 research vessels now in use, most of which are very small in size and most of which are inefficiently adapted to research instead of having been built specifically for such purposes.

UNIQUE RADIO TELESCOPE BEING CONSTRUCTED IN OHIO—The design, engineering, and construction of two 360-ft long antennas are being undertaken by a team of students under the direction of John D. Kraus of Ohio State University with the aid of grants from the National Science Foundation. The students work on a part-time basis during the school year and on a full-time basis during the summer. The radio telescope is of unique design which will permit the mapping of the radio sky at minimum cost. When completed it will consist of a fixed parabolic antenna 360 ft long and 70 ft high, a flat tiltable reflector 360 ft long and 100 ft high, and the associated radio receiving equipment. It is expected to go into operation in 1960.

The radiation from the area of the sky under observation will be received on the tiltable antenna and reflected to the fixed antenna, thence to the receiver where it will be recorded. The collecting area of the tiltable antenna will be approximately equivalent to that of a 170-ft diameter steerable dish antenna but will involve a cost of only about one-tenth as much. The location is near the Perkins Observatory of Ohio Wesleyan University, about 15 mi north of Columbus.

MEMBERSHIP OF THE WORLD METEOROLOGICAL ORGANIZATION REACHES 100—The World Meteorological Organization proudly announces that with the adherence of Saudi Arabia, Nicaragua, and Mauritius the total membership in WMO is 100. Mauritius was formerly included in the membership of the British East African Territories and has only recently been given a separate membership listing. There are two categories of membership—member states, which total 77; and territories or groups of territories, which total 23.

SUMMER STUDENT FELLOWSHIPS AT WOODS HOLE OCEANOGRAPHIC INSTITUTION—The fellowship pro-

gram, now in its 29th year, is designed to afford students the opportunity to pursue advanced studies in oceanography under the supervision of members of the staff of Woods Hole Oceanographic Institution. No degrees, credits, examinations, or grades are given, though a certificate of accomplishment may be issued. For the coming summer 98 applications were received from 22 colleges and universities in the United States, India, Japan, and Sweden. Ten students have been awarded summer fellowships. In addition, three graduate fellowships are offered which permit a student to take his doctorate at the university of his choice. More details concerning the program may be secured from the Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

THIRD SYMPOSIUM ON ROCK MECHANICS—The Third Symposium on Rock Mechanics was held at the Colorado School of Mines, April 20-22, 1959. The Symposium is an annual event cosponsored by the Colorado School of Mines, the University of Minnesota, and Pennsylvania State University, and was supported with the aid of a grant from the National Science Foundation. Themes of the four sessions were: Nuclear Blasts in Mining, including the use of nuclear explosions to release oil shale; Seismology and Explosions; Factors Common to Soil Mechanics and Rock Failures; and Factors Common to Communion.

The same three schools share a rotating host program, and earlier this year a Symposium on Drilling and Blasting was held at the University of Minnesota; later this year one on Exploration Drilling will be held at Pennsylvania State University.

Radiocarbon Supplement TO BE PUBLISHED BY THE AMERICAN JOURNAL OF SCIENCE—This supplement, devoted wholly or largely to the publication of radiocarbon date lists from laboratories throughout the world, appeared in May, 1959, and will hereafter appear as one volume in each year. There will be a separate subscription list for this supplement. The price for Volume 1 was \$2.50. Communications should be sent to the American Journal of Science, Box 1905A, Yale Station, New Haven, Connecticut.

SPECIAL NUMBER OF *Geophysica* PUBLISHED TO HONOR ERIK H. PALMÉN—*Geophysica*, Volume 6, Number 3-4, Meteorology, is a special issue of this journal to mark the occasion of the sixtieth birthday of Erik H. Palmén. The issue contains 27 papers (nearly 400 pages) by distinguished meteorologists and other geophysicists on various phases of geophysics, bearing chiefly on meteorology, and is available from the Geophysical Society of Finland at a price of \$6.00.

NEW HIGH-ALTITUDE PROGRAM OF THE WEATHER BUREAU—Taking cognizance of the need for jet age forecasting charts for levels between 20,000 and 45,000 ft, the Weather Bureau has announced

the inauguration of a special facsimile network for the transmission of 43 high-level weather charts each day in order to provide pilots of jet and turbo-prop aircraft with the latest aviation weather information.

BROADENED AIRCRAFT COVERAGE OF HURRICANE RESEARCH—The U. S. Weather Bureau has recently entered into a lease arrangement with Trans Caribbean Airways, Inc. for the use of two Douglas DC-5-AB aircraft in hurricane research flights. These will be equipped with especially designed meteorological instruments to measure and record various meteorological items continuously while the aircraft is flying within a tropical storm. In addition to these aircraft, which will be used in middle- and low-level flights, the Weather Bureau also has the use of a B-57 twin-engine light bomber to carry out important atmospheric investigations at elevations of up to 50,000 ft. The 'hurricane hunter' aircraft of the Navy and the Air Force will continue their storm location and tracking flights over the south Atlantic, the Caribbean Sea, and the Gulf of Mexico, as in previous years.

RESULTS OF STUDIES ON GRINNELL AND SPERRY GLACIERS—A recent report on these glaciers in Glacier National Park, Montana, has been released to open file by the U. S. Geological Survey at its offices in Washington and various other locations. The survey covers the annual changes that have been made year by year since 1949, noting that the changes during the past two years have been more pronounced than any in the previous years studied. Grinnell Glacier lowered ten to 15 ft during the period 1956 to 1958, while from 1950 to 1956 the net lowering was one to two feet. The borders and the front did not change appreciably. Sperry Glacier in its central portion lowered from 9 to 13 ft from 1956 to 1958, while the net change from 1949 to 1956 was an increase of five to ten feet. The 4000-ft front of the glacier has also showed a marked recession during the two years 1956-1958.

WORK OF THE COOPERATIVE OBSERVERS OF THE U. S. WEATHER BUREAU—The U. S. Weather Bureau has some 7000 cooperative weather observers who record weather observations daily, this being purely a volunteer service. In citing these recently, F. W. Reichelderfer, Chief of the Bureau, noted that there are now 21 cooperative observers who have each served over 60 years. For many years and even up to the present these cooperative observers have provided the backbone of the detailed climatic data available in the United States. In recent years, though there have been many new developments in the field of meteorology, the volunteer cooperative observer group still provides an important source of information on meteorological and climatic data.

CURRENT OCEANOGRAPHIC STUDIES AT SCRIPPS INSTITUTION—Between February and May, 1959, the

Vermillion Sea Expedition of the Scripps Institution, in cooperation with the University of Mexico, carried out geophysical, geological, and biological explorations in the Gulf of California, using the Scripps research vessels *Horizon* and *Spencer F. Baird*. Special studies of the sea-floor sediments by grab-samplers and by gravity and piston-corers and biological trawling and dredging in the basin on the shelf and on the slopes were undertaken. The work involved precise bathymetric investigations of basins, slopes, and submarine canyons and SCUBA diving in shallow canyon heads, as well as hydrographic studies by water-sampling and bathythermograph measurements and other studies involving seismic, magnetic, and gravity measurements.

At the same time a group of scientists from Scripps Institution of Oceanography cooperating with scientists from Mexico and the U. S. Navy Electronics Laboratory will undertake a cooperative project on the Holocene and upper Pleistocene sediments of the coastal plain-continental shelf of the east side of the Gulf of California, the objective being to study geological, biological, archeological, and oceanograph details of the sedimentary complex on the shallow flanks of a modern geosyncline. A second trip is tentatively planned covering coring, bathymetry, and sonar studies in November and December, 1959, with the third and final trip related to this reconnaissance phase sometime during 1960.

BROADENED HEAT-BUDGET STUDIES UNDERTAKEN BY THE UNIVERSITY OF WISCONSIN—University of Wisconsin scientists under the guidance of Reid A. Bryson are undertaking extended studies on the energy-budget, using lakes as prime instruments in this study. It is noted that the convenient thing about a lake heat budget is that it summarizes the events of climate and weather, integrating them into an easily calculated quantity. By measuring water temperatures at regular intervals throughout the year, it is possible to arrive at a summary figure characteristic of the area in which the lake is situated. On the initial pilot study begun in April, 1958, ten sites located roughly on a line between Lake Mendota at Madison and Zed Lake at latitude 57° in northern Manitoba were selected. Using the data determined during the last year, relationships between climate and vegetation are being studied, and appropriate plans are being made for the continuation of the work into the future.

NEW RESEARCH VESSEL OF WOODS HOLE OCEANOGRAPHIC INSTITUTION—Woods Hole Oceanographic Institution has recently added the 214-foot research vessel *Chain* as its fourth ship in its ocean-going research fleet. The ship's first cruise covered a traverse from Nova Scotia to Bermuda over a period of 16 days. It holds four large laboratories, a crew of 33, and 28 scientists. Early in 1959 it undertook a three and one-half month trip to the South Atlantic between South America and Africa,

and in early May departed on a three-months' cruise to the Mediterranean.

RESEARCH SUBMARINE—The USSR has converted one of its submarines into a research vessel attached to one of the Research Institutes. The vessel is especially oriented towards fisheries.

PROJECT HUGO OF THE OFFICE OF NAVAL RESEARCH—Project HUGO (highly unusual geophysical operations) is being undertaken with the cooperation and assistance of the Bureau of Aeronautics and the Weather Bureau and is specifically designed to study meteorological phenomena, believing that it may have applications to improving weather forecasts and of particular use in the Weather Bureau's Hurricane Weather Research Project. The recent firing of a Nike-Cajun with recoverable instrument head secured clear pictures showing weather frontal systems and their associated cloud formations from high altitudes over ocean areas where there are no regular weather stations. The successful rocket fired on December 5, 1958, reached an altitude of about 86 miles. The plans for 1959 include the firing of several similar rockets. Because the head containing the camera is recoverable, the cost is greatly reduced and amounts to about \$7000 per firing.

NEW PROGRAM OF WATER STUDIES IN THE U. S. GEOLOGICAL SURVEY—A new scientific and engineering program of the Water Resources Division of the U. S. Geological Survey, while it will still stress the collection of basic data, will also take into greater account our growing water needs both with regard to quantity and quality, noting that if problems of flood and drought are not successfully met we must not only have data bearing on these events but much more attention must be given to the interpretation of these data. The announcement relating to this calls attention to the 13 programs ranging from river basin studies to land subsidence because of water or oil withdrawal and glaciological research.

NEW COMMANDER FOR THE AIR WEATHER SERVICE—H. H. Bassett, Major General in the Air Force, has been named Commander of the Air Weather Service, with Norman L. Peterson, Brigadier General, as Vice Commander. In June, 1958, the Air Weather Service moved from Andrews Air Force Base near Washington, D. C., to Scott Air Force Base, Illinois.

NEW EDITORIAL STAFF FOR *Mathematical Tables and Other Aids to Computation*—The Division of Mathematics of the National Academy of Sciences—National Research Council has announced that Harry Polachek, Technical Director of the Applied Mathematics Laboratory of the David Taylor Model Basin, has been appointed Chairman of the new Editorial Committee for the quarterly journal *Mathematical Tables and Other*

Aids to Computation, succeeding C. B. Tompkins of the University of California. This work was undertaken in 1943 with the aid of a grant from the Rockefeller Foundation. The publication features original papers in numerical analysis, high-speed computer methods, and other aids to computation, as well as short articles reporting on the latest developments in these fields. The group serves as an information center on tables and other aids to computation bearing on most aspects of the physical sciences, including geophysics. Articles should be sent to Editor Harry Polachek at the David Taylor Model Basin, Washington 7, D. C. Subscriptions should be placed with the Printing and Publishing Office of the National Academy of Sciences, Washington 25, D. C.

Arid Zone: NEW PUBLICATION OF UNESCO—The Arid Zone has been made a major project of scientific research by UNESCO, and in order to develop this program properly a new publication entitled *Arid Zone* has been established, Volume 1, Number 1, appearing in August, 1958 as an off-set pamphlet of 16 pages. The first number includes word of the Arid Zone Research Program, the Fourteenth Session of the Advisory Committee, the National Cooperating Committees for the Project, the Teheran Symposium on Salinity Problems, the Course on Plant Ecology in the Middle East held in February-March, 1958, Publications in Preparation, Activities Relating to the Demineralization of Saline Water, and similar materials. The United States National Commission for UNESCO announces that they "will . . . welcome names of additional recipients who . . . would find the 'Newsletter' valuable in their work." Send word to the office of AGU or to the office of UNESCO in Paris. Citizens of the United States may also send word of such desire to the UNESCO Relations Staff, Department of State, Washington 25, D. C.

NEW STUDY COMMISSIONS FOR RIVER BASINS—The Eighty-Fifth Congress, Public Laws 85-850 and 85-843, established United States Study Commissions for river basins in the Southeast and in Texas, these Commissions being an outgrowth of the experience gained in previous efforts to obtain integrated plans for the development of land and water resources. The plan contemplates a collaborative approach to planning where Federal, state, and local interests, public and private, may be heard and considered. The Commissions are independent Federal agencies with membership appointed by the President.

ADVANCED SHORT COURSE OF THE BAVARIAN BIOLOGICAL RESEARCH CENTER—An advanced course on the biology of waste water on the theme "Possibilities and Limits in Removing Poison and Radioactive Substances from Sewage and Industrial Waste Waters" will be held at the Bayerische Biologische Versuchsanstalt in Munich, October 5-

9, 1959, under the direction of Dr. R. Demoll and Dr. H. Liebmann. Interested persons should write to the Bayerische Biologische Versuchsanstalt, Veterinärstrasse 13, München 22, Germany.

EARTH SCIENCES IN THE ROYAL ONTARIO MUSEUM—The Royal Ontario Museum announces a change of name from the Division of Geology and Mineralogy to the Division of Earth Sciences, noting that, although there is no change in staff, there is the plan to enlarge the scope of operations in the broad field of the Earth sciences.

SIXTH CONGRESS OF THE INTERNATIONAL ASSOCIATION ON QUATERNARY RESEARCH—This Congress will be held in Warsaw and Cracow, Poland, in 1961, the exact dates not yet announced. The last such Congress was held in Madrid and Barcelona in 1957. Those interested in taking part in this Congress should write to Prof. Rajmund Galon, Geographical Institute, University, Toruń, Poland, who is Secretary General of the Sixth Congress.

JOINT SEISMIC STUDIES OF COLUMBIA UNIVERSITY AND CALIFORNIA INSTITUTE OF TECHNOLOGY—Under the joint direction of Maurice Ewing, Director of Lamont Geological Observatory of Columbia University, and Frank Press, Director of the Seismological Laboratory of the University of California, studies are under way tracing earthquake waves across the United States. These studies to date, reported in a recent issue of the *Bulletin* of the Geological Society of America, indicate that the bottom of the continental crust tends to mirror the surface, being considerably thicker under mountain ranges in the western part of the country, shallower in the plain states, and slightly thicker again under the Appalachian Mountains in the East. The variation ranges from slightly less than 20 mi to nearly 32 mi thick.

TENTH PACIFIC SCIENCE CONGRESS—The Tenth Pacific Science Congress will be held in Hawaii in August-September, 1961. The President of the Congress is the newly installed President of the University of Hawaii, Laurence H. Snyder. The Secretary-General is Harold J. Coolidge, Executive Director of the Pacific Science Board, National Academy of Sciences—National Research Council, Washington 25, D. C.

THE NAMING OF MOUNT HUBLEY—A mountain reaching to an elevation of 8915 ft in the Romanof Mountains (69° 16' 35" N, 143° 47' 44"

W), 6 miles west of the Jago River and ten miles east-southeast of Mount Michelson, in Alaska, has been named Mount Hubley in memory of Richard C. Hubley, coordinator of IGY glaciological work sponsored by the United States in the northern hemisphere and leader of the IGY McCall Glacier party, who died on McCall Glacier on October 28, 1957.

EFFORTS TO IMPROVE SCIENCE LABORATORY FACILITIES IN SCHOOLS—The National Science Foundation has invited scientists and science teachers to submit proposals for the construction of better laboratory equipment for use in the nation's schools. Proposals judged to be meritorious will receive support from the Foundation to encourage the development of inexpensive and practical tools for use in various laboratory phases of science instruction. At a recent open house of the National Science Foundation some of these devices were exhibited and received considerable favorable comment, being both simple in construction and illustrating important physical principles. Further information can be secured by writing to the Course Content Improvement Section, Division of Scientific Personnel and Education, National Science Foundation, Washington 25, D. C.

COST OF FINDING NEW OIL SUPPLIES—At a recent meeting of the American Association of Petroleum Geologists, a paper was presented by R. E. Megill, Senior Economist for the Carter Oil Company, which indicated that the cost of finding new oil supplies is now increasing at a faster rate than development and operating costs in most areas of the United States and that we face the problem of finding more new oil at less cost. His paper gave much detail in support of this statement, showing, for example, that in the Oklahoma-Kansas area the cost of finding oil has increased from \$0.35 to \$1.30 per barrel from 1942 to 1957, while at the same time the operating costs have increased from \$0.86 to \$1.56.

NEW DIRECTOR FOR AIR FORCE CAMBRIDGE RESEARCH CENTER'S GEOPHYSICS RESEARCH DIRECTORATE—Ernest A. Pinson, Colonel, U. S. Air Force, has been designated as Director of the Geophysics Research Directorate, AFRCR. He is the holder of two Ph.D. degrees, one in human physiology from the University of Rochester and one in nuclear physics from the University of California. He has previously served as Chief of the Biophysics Division of the Air Force Special Weapons Center at Albuquerque, New Mexico.

Personalia

MAURICE L. ALBERTSON, Director of the Research Foundation of Colorado State University, has recently been in Thailand while on an operational survey in connection with the establishment of a graduate school of engineering.

WILLARD BASCOM, who formerly served as Executive Secretary of the Maritime Committee of the National Academy of Sciences—National Research Council, has been named Chairman of the NAS-NRC's Committee that is considering the

matter of drilling a hole through the Earth's crust to the Mohorovicic discontinuity.

LOUIS J. BATTAN, Associate Director of the Institute of Atmospheric Physics, University of Arizona, has been elected a Councilor of the American Meteorological Society.

BASIL E. BELL, formerly of Nairobi, Kenya, has undertaken duties as a hydrologist and oceanographer with the East African Marine Fisheries Research Organization at Zanzibar.

E. WILLARD BERRY, Professor of Geology at Duke University, is devoting the months of April-July, 1959, on the study of coal in Australia.

J. A. B. BJERKNES, Professor of Meteorology at the University of California at Los Angeles, has been named the recipient of the International Meteorological Organization Prize by the World Meteorological Organization. The prize is in recognition of his considerable contributions to meteorological science since 1919. This is the fourth award. Previous recipients have been Th. Hesselberg of Norway, Carl-Gustav Rossby of Sweden and the United States, and E. Gold of the United Kingdom.

EUGENE BOLLAY has been appointed Director of Research on Meteorological Instrumentation at BJ Electronics of the Borg-Warner Corporation in Santa Ana, California. Formerly he was President and Technical Director of Northam Electronics, Inc., which was recently acquired by BJ Electronics.

HENRY G. BOOKER has been named Chairman of the School of Electrical Engineering at Cornell University.

JULE G. CHARNEY, Director, Dynamical Weather Prediction Project, Massachusetts Institute of Technology, has been elected a Councilor of the American Meteorological Society.

JOHN F. CLARK, formerly Head of the Atmospheric Electricity Branch at the U. S. Naval Research Laboratory, has been named Chief, Planetary Sciences Programs in the Office of the Assistant Director for Space Sciences of the National Aeronautics and Space Administration. In this position he is responsible for the planning and implementation of the national space sciences research program in such areas as atmospheric and ionospheric physics, chemical aeronomy, and associated electric and magnetic phenomena of the Earth and other planets.

ALBERT P. CRARY has recently returned to the United States after two and one-half years in the Antarctic as Deputy Chief Scientist on the U. S. Antarctic Program of the IGY. He also served as

Station Scientific Leader at Little America, from which station he led two major journeys of scientific exploration, the second ending only in February, 1959. The traverses covered over 3000 mi. Other traverses organized under his direction brought the total up to 7500 mi, spanning the Antarctic from the Weddell Sea to the Ross Ice Shelf and into the Victoria Land Plateau. His first trek, from October 24, 1957, to February 13, 1958, covered 1450 mi of the Ross Ice Shelf; and the second journey which began October 15, 1958, lasted for 108 days and covered over 1600 mi and included the climbing of Skelton Glacier to a height of 7500 ft, placing markers which will lay the groundwork for the first accurate measurements of mass ice flow down the glacier. Their findings included a determination of the ocean bottom depth beneath the Ross Ice Shelf of about 4400 ft below sea level measured by seismic sounding. The trips were undertaken by means of three Sno-Cats, the first of which carried an electronic crevasse-detector, navigation equipment, and a radio. Another housed the seismic, gravity, and magnetic equipment; and the third carried messing facilities. The party was resupplied from time to time by ski-equipped aircraft.

The surface profiles along the traverse routes were determined by means of altimeters and transit levelling. Ice thickness was determined by seismic reflection methods and rock characteristics under the ice by seismic refraction methods. Data were taken on annual snow accumulation by means of pits and bore holes, and snow hardness, grain size and shape, densities, and temperatures were observed. Meteorological observations included temperature, pressure, wind speeds and direction, cloud cover, and cloud types.

Stops were made at intervals of about 30 mi for the various studies such as those made for snow pits and by seismic determinations. At intervals of five miles stops were made for gravity and magnetic observations.

GORDON E. DUNN, in charge of the U. S. Weather Bureau's Hurricane Forecast Center, recently received the Gold Medal citation for his outstanding contributions to the public service in the field of hurricane warnings.

HERBERT H. FRIEDMAN of the Naval Research Laboratory has been appointed Superintendent of the Atmosphere and Astrophysics Division.

H. RICHARD GAULT, Professor of Geology, has been designated Head of the Department of Geology at Lehigh University, effective July 1, 1959.

H. E. HEDGER, Chief Engineer of the Los Angeles County Flood Control District, has recently retired.

GEORGE B. HESS of Princeton, New Jersey, currently a student at Stanford University, has been

named a recipient of the Leeds and Northrup fellowship. These fellowships were established in 1956 to give advanced training to outstanding scholars in the fields of physics and chemistry.

WILLIAM E. HAYT, Chief, Hydrologic Services Division of the U. S. Weather Bureau, has been appointed by President Eisenhower to membership on the United States Study Commission for Southeast River Basins as a representative from the Department of Commerce.

HENRY G. HOUGHTON, Head, Department of Meteorology, Massachusetts Institute of Technology, has been elected a Councilor of the American Meteorological Society.

DON KIRKHAM, Professor of Soils and Physics at Iowa State College, recently presented the annual Sigma Xi honor lecture at Iowa State College on the subject "Soil physics, some problems solved, some unsolved."

MAX A. KOHLER, Chief Research Hydrologist at the headquarters of the U. S. Weather Bureau in Washington, recently received the Gold Medal citation of the Department of Commerce for his contributions in the field of hydrology through leadership and stimulation of applied research and development.

PHILIP E. LAMOREAUX, formerly Division Hydrologist of the Mid-Continent Area of the Water Resources Division, U. S. Geological Survey, has been named Chief of the Ground Water Branch, succeeding A. Nelson Sayre, who had held the post since 1946 as a successor to the late O. E. Meinzer, former President of the AGU.

JOHN W. MAUCHLY, Director of UNIVAC Applications Research Center of Remington Rand, has been named to the Science Information Council of the National Science Foundation.

KENNETH M. NAGLER, Research and Development Meteorologist with the U. S. Weather Bureau's Office of Meteorological Research in Washington, has received the Silver Medal citation of the Department of Commerce "for valuable contributions to national safety and welfare through important research on the application of meteorology to problems in the field of radioactive fallout."

ROBERT M. PAGE, Director of Research at the U. S. Naval Research Laboratory, was designated as the recipient of the third annual Captain Robert Dexter Conrad Award of the Office of Naval Research "for his outstanding contributions to science—especially in the fields of radio communications, radar and electronics—and for his dedicated service to the Navy as a civilian scientist."

HANS A. PANOFKY, Department of Meteorology, Pennsylvania State University, has been elected a Councilor of the American Meteorological Society.

EUGENE L. PECK, Meteorologist and Hydrologist with the U. S. Weather Bureau's Water Supply Forecast Unit, Salt Lake City, Utah, has been given the Silver Medal citation of the Department of Commerce "for important contributions to the public service through excellence in water supply forecasting, and for the development of forecasting procedures."

E. R. PIORE, Director of Research, IBM Corporation, has been named by President Eisenhower to be a member of his Science Advisory Board.

MARSHALL M. RICHARDS, Hydrologist with the U. S. Weather Bureau's River Forecast Unit in Knoxville, Tennessee, has received the Silver Medal citation of the Department of Commerce "for extremely competent performance in carrying out important assignments, and for significant service to the advancement of the Weather Bureau's program of hydrology."

MORTON J. RUBIN, Meteorologist for the U. S. Weather Bureau, has recently returned from Mirny Station of the U.S.S.R. in Antarctica. He conducted a daily program of upper-air analysis for the Soviet group, took many time-lapse color pictures of clouds, and collected snow crystal replicas. He notes that there was a free exchange of scientific information with the Russian scientists at Mirny and the interior stations of the Soviet Union in Antarctica. He has been named Head of the newly created Polar Meteorological Research Unit, which will coordinate Weather Bureau research activities in the circulation of the atmosphere and heat-water budget studies. In the Antarctic he succeeded Gordon Cartwright, who served at the Mirny station during the first part of the IGY.

A. NELSON SAYRE, who has retired as Chief of the Ground Water Branch of the U. S. Geological Survey, has taken up broad duties in research in the U. S. Geological Survey based on his extensive experience in ground-water hydrology.

GERHARD F. SCHILLING, formerly Special Assistant to the Director of the Smithsonian Astrophysical Observatory, has been appointed Chief, Astronomy and Astrophysics Programs in the Office of the Assistant Director for Space Sciences of the National Aeronautics and Space Administration. His responsibilities include program planning and project activation in interplanetary and interstellar physics, observational astronomy, stellar physics, and such areas as lunar and planetary surface explorations, gravitational and magnetic fields, energetic particles, and solar studies.

HARRISON W. STRALEY, III, has discontinued his commercial connections to devote full time to leading the activities of the Mineral Engineering Group, Material Sciences Division, Engineering Experiment Station, at Georgia Institute of Technology.

HERBERT C. S. THOM, Chief Climatologist of the U. S. Weather Bureau's Office of Climatology in Washington, has received the Silver Medal citation of the Department of Commerce "for valuable public service through investigation and application of meteorological statistics and engineering techniques to the agricultural and industrial economy of the United States."

BRADFORD WILLARD, who has been Head of the Department of Geology of Lehigh University since 1939, will retire as Department Head on June 30, 1959.

RICHARD ALLEN BRAMKAMP, Chief Geologist of the Arabian American Oil Company, died September 1, 1958, at the age of 48, in New York City after a long illness. He was born at Richmond, Indiana, and took his baccalaureate degree from Pomona College in California. He took his doctorate from the University of California at Berkeley in 1934. After two years of work in the Museum of Paleontology at the University, he joined the staff of Standard Oil Company of California as a paleontologist and shortly took up duties in Arabia where he spent most of his professional life and did much to discover and develop the oil fields of Saudi Arabia. He had been a member of AGU since 1947.

DAVID DONOGHUE, Consulting Petroleum Geologist, died in Mexico City on October 15, 1958, at the age of 67. He was born in San Antonio and took his baccalaureate degree from St. Mary's College in 1909, studying subsequently at the University of Texas. He entered into consulting geological work in the 1920's, previous to which he was connected with the Marland Oil Company (now Continental Oil Company). His consulting work in petroleum geology covered a wide field geographically, including the United Nations mission to Lybia just shortly before his death. He held important posts with various companies, for example, served as President of Federal Royalties Company from 1933 to 1951, and at the time of his death was President of Lasca, Inc. He had been a member of the AGU since 1945.

HARVEY BANKS KINNISON, who retired as Area Chief of the U. S. Geological Survey's Surface Water Branch for the Western States as of the beginning of this year after more than 40 years of service, died March 14, 1959, at the age of 68. He was born at Hopkins, Missouri, and took his baccalaureate degree from the University of Idaho

in 1914. He began his professional work as Deputy County Engineer for Bonner County, Idaho, and took up duties with the Colony Colding Corporation which he served until 1918. He entered the service of the U. S. Geological Survey in 1918, working in Texas, Kansas, Massachusetts, and California. He served as District Engineer in the New England area for about 30 years. He had been a member of AGU since 1934.

GERARD HENDRIK MATTHES, Consulting Engineer, specialist in hydraulic and hydrologic problems, died in New York, April 8, 1959, at the age of 85. He was born in Amsterdam, The Netherlands. He took his baccalaureate degree at MIT in 1895 and began his professional career as an instrumentman and draftsman for the Town of Brookline, Massachusetts, subsequently working for the Massachusetts State board of Harbor and Land Commissioners. In 1902 he took up duties with the U. S. Geological Survey on stream gaging and irrigation studies, and in 1907 he entered the employ of the Bureau of Reclamation. In 1913 he entered the service of the Pennsylvania State Water Supply Commission on Flood Control Studies, and from 1915 to 1920 was with the Miami Conservancy District at Dayton, Ohio. From 1920 to 1923 he took up duties with the Corps of Engineers on surveys of the Tennessee River and its tributaries, and from 1923 to 1928 established an office as consulting engineer in New York, specializing in aerial surveys and maps. He returned to the Corps of Engineers in 1929, becoming Principal Engineer in the office of the President of the Mississippi River Commission, and was Director of the U. S. Waterways Experiment Station. Since his retirement in 1945 he has been in residence in New York, frequently being called upon as consultant on various hydraulic and hydrologic problems. He had been a member of the AGU since 1932.

ROBERT M. OVERBECK, until his retirement in January, 1957, a geologist of the State of Maryland, died on September 23, 1958, at his home in Ruxton, a suburb of Baltimore, at the age of 71. He was born in Baltimore and took his baccalaureate degree from Johns Hopkins University in 1909, and following two years of work as a teacher, reentered Johns Hopkins University in 1911 and received his doctorate in 1915. At that time he entered the service of the U. S. Geological Survey, doing extensive field work in Alaska, which was then remote and difficult country. He spent a year in 1919-1920 on a survey of Bolivian tin fields and upon his return joined the Geologic Staff of the Shell Oil Company. In 1924 he returned to Bolivia in the service of the Guggenheim interests, subsequently taking up residence in Sweden and continuing his work with the Guggenheim interests. From 1933 to 1935 he was engaged in studies of mining properties in the United States and Mexico. In 1935 he went to the Philippines where five

years later he was interned as a prisoner of the Japanese, returning to this country after his liberation and taking up duties in the Department of Geology, Mines, and Water Resources of the State of Maryland, which work continued until his retirement. He had been a member of the AGU since 1947.

CARL ROHWER, for many years Irrigation Engineer for the Department of Agriculture, died in

Fort Collins, Colorado, January 14, 1959. He was born in Calhoun, Nebraska, took his baccalaureate degree from the University of Nebraska in 1912, and a professional degree in Civil Engineering from Cornell University in 1913. He was considered a world-wide authority on many aspects of hydrology and hydraulics as they relate to irrigation and conducted much research on evaporation, seepage, and other problems. He had been a member of AGU since 1932.

Union, Section, and Committee Activities

Fortieth Annual Meeting (1959)

Minutes, General Assembly and Section Meetings

SYMPOSIUM ON COSMIC-TERRESTRIAL RELATIONSHIPS

This Symposium was arranged by W. O. Roberts and held in the Great Hall of the National Academy of Sciences on the afternoon of May 4, 1959. The session opened at 14h 00m and adjourned at 17h 00m.

The Symposium consisted of two organized discussions on highly speculative subjects, which stimulated informal debate. The first, on "Solar and Other Cosmic Influences on Planetary Weather and Ionospheres," was introduced by Seymour Hess (Florida State University), and included discussions principally of Mars, Venus, and Jupiter atmospheric phenomena. Invited comments were presented by Albert G. Wilson (Rand Corporation), Roger Gallet (National Bureau of Standards), William M. Sinton (Lowell Observatory), and B. F. Burke (Carnegie Institute Washington, Department of Terrestrial Magnetism). The first discussion was attended by approximately 180.

The second session dealt with "Influences of Variable Solar and Other Cosmic Phenomena on Terrestrial Weather" and was introduced by Clarence E. Palmer, Institute of Geophysics, University of California. Invited contributions were presented by Ralph Shapiro (Geophysics Research Directorate, Air Force Cambridge Research Center), R. A. Craig (Florida State University), Glenn W. Brier (U. S. Weather Bureau), W. L. Godsen (Meteorological Service of Canada), and Walter O. Roberts (High Altitude Observatory, University of Colorado). It presented, principally, a survey of the apparent influences of changing solar activity on climatic and short-term weather phenomena, including principally suggested correlations of geomagnetic storm with meteorological phenomena. The session was attended by approximately 125.

Smoker

The Smoker was held in the Ball Room of the National Press Club, National Press Building, 14th and F Streets, N.W., Washington, D. C., on the evening of Monday, May 4, 1959. There were between 400 and 500 in attendance. This was a purely informal gathering to provide a pleasant opportunity for those in attendance to greet old friends and to make new acquaintances. The occasion was one of ever-changing small discussion groups.

Evening Session

Preceding the evening session there was a subscription dinner at the Statler Hotel in honor of Walter Maurice Elsasser, the twenty-first William Bowie Medal recipient. This was attended by 84 persons.

The evening session was called to order by Vice President Lloyd V. Berkner at 20h 30m, Tuesday, May 5, 1959, in the Lecture Room of the National Academy of Sciences. The room was filled to capacity with about 230 in actual attendance, a number having to be turned away. After appropriate welcoming remarks, Vice President Berkner called on Merle A. Tuve, who, on behalf of the William Bowie Medal Committee, cited Walter Maurice Elsasser of the Scripps Institution of Oceanography as the twenty-first recipient of the Medal in accordance with the remarks set forth in the early pages of this issue. Vice President Berkner then made the presentation, and the recipient indicated acceptance in his response, likewise set forth in the early pages of this issue.

At the close of this, Vice President Berkner introduced President Maurice Ewing, who gave his presidential address on recent explorations in the South Atlantic off the coast of Argentina on the subject, The Scotia Sea Floor. It is anticipated that this will subsequently be published in the *Transactions* or in the *Journal of Geophysical Research*.

At the close of his address a social hour with refreshments was held in the Great Hall of the National Academy of Sciences.

General Assembly: Papers on Frontiers in Geophysics and Business Meeting

The General Assembly was called to order by President Maurice Ewing at 14h 00m, Wednesday, May 6, 1959, in the Great Hall of the National Academy of Sciences with about 250 in attendance. The following program was presented:

H. H. HESS: The AMSOC Deep Hole to the Mantle

GORDON J. F. MACDONALD and WALTER H. MUNK:
Tides and the Length of Day (presented by
WALTER H. MUNK)

W. O. ROBERTS: Recent Progress in Solar Physics
After each paper an opportunity was given for discussion from the floor.

After a brief recess the Business Meeting was called to order at 16h 10m.

The minutes of the Business Meeting of the 39th Annual Meeting [see *Trans.*, 39, 557-559, 1958] were approved.

SUMMARY REPORT OF THE GENERAL SECRETARY

Details of the AGU's work during 1958 appear in the minutes of the Executive Committee in the August 1958 issue of our *Transactions* (pages 755-758) and in the December 1958 issue (pages 1183-1187), and an account of the activities of the Union since the Executive Committee meeting in October 1958 will be published in the *Transactions* of September, 1959. These are briefly summarized here.

Elections of officers have taken place for the Union including its eight Sections and the Regional Committees. The new officers of the Union are Lloyd V. Berkner, President; F. W. Reichelderfer, Vice President; and I will serve again for the upcoming triennium as General Secretary. The new officers for the eight sections were announced at their opening sessions.

Financially, the Union is in better position than last year, owing in large part to a grant of \$75,000 from the National Science Foundation to subsidize the publications, but in part to a substantial increase in new members that has resulted from an extensive campaign to emphasize the advantages of membership in the AGU.

There are still many qualified persons who are not now members and should be. We are expecting your individual assistance in soliciting applications of eligible persons among your acquaintances. A directory appears in the April 1957 issue of the *Transactions* (a new one will be issued in the September *Transactions*), which should be of help to you in telling who are members. Application forms appear from time to time in both the *Journal of Geophysical Research* and the *Transactions*. We are also seeking more corporation members. The summary of membership since our last annual meeting is as follows:

Membership as of April 21, 1958	5008
Reactivated	24
New members (including 76 applications now being processed. Approximately 700 have been elected since the beginning of the year.)	957 5089
Resigned	151
Inactive	6
Dropped	18
Deceased	25 200
Membership as of April 21, 1959	5789

The deceased reported since our last annual meeting are as follows:

L. James Bulkley (date unknown)
 Jack M. Terry (date unknown)
 Robert L. Pendleton, June 23, 1957
 Albert C. Hornady, July 5, 1957
 Luke A. Cole, September 2, 1957

James B. Cullison, Jr., February 2, 1958
 Harry O. Wood, February 4, 1958
 Victor H. Jones, March 6, 1958
 Hebley B. Churchill, March 25, 1958
 Mark R. Kulp, June 1958
 Townsend Cromwell, June 1, 1958
 Willie O. Byrd, July 6, 1958
 A. L. McCuiston, July 9, 1958
 E. J. Kolkmeier, August 18, 1958
 R. A. Bramkamp, September 1, 1958
 W. W. Horner, September 22, 1958
 Robert M. Overbeck, September 23, 1958
 David Donoghue, October 15, 1958
 R. G. Hoiles, October 10, 1958
 William Schriever, November 20, 1958
 Jackson H. Wilkinson, November 29, 1958
 Thomas J. Mitchell, December 29, 1958
 Carl Rohwer, January 14, 1959
 Harvey B. Kinnison, March 14, 1959
 Gerard H. Matthes, April 8, 1959

The new monthly *Journal of Geophysical Research* has been favorably received. Numbers 1 to 4 inclusive (January to April) have been distributed. Number 5 (May) will go in the mail this week, and Number 6 (June) is now in the galley-proof stage.

The *Transactions* of 1959 are being issued quarterly, and the first number (March) has been distributed. The June issue of the *Transactions* is now at the printer's.

We need more advertising in both the *JGR* and the *Transactions* and your help on this is solicited.

The Editorial and Publication Committee held its last meeting on November 20, 1958, and in accordance with the revised Statutes and By Laws, its duties were transferred to an editorial board whose chief Editors are Drs. Philip Abelson and James Peoples.

Geophysical Monograph Number 2 was issued in July 1958; Monograph Number 3 is now in the hands of the printer and is scheduled for delivery on June 1. We expect to issue Monograph Numbers 4 and 5 before the end of the year.

The Johnson Reprint Corporation has completed the reprinting of Volumes 1, 2, 4, 6 to 12, inclusive, of our *Transactions* and is about to complete Numbers 13, 14, and 15. They may be purchased from Johnson Reprint Corporation, 111 Fifth Avenue, New York 3, New York.

Translation of *Izvestiya* for 1958 is moving along quite satisfactorily. Number 1 is in the hands of the printer; the translation of Number 2 is complete and Numbers 3 and 4 are in progress. By late summer or early fall the volume for 1958 will be complete and we can begin with Number 1 of 1959. W. S. Jardetzky has undertaken the work as Translation Editor.

Pergamon Press has completed Numbers 1 through 11 of *Izvestiya* for 1957 and has supplied us with proof of Number 12. We are working out arrangements to have the complete stock brought

to this country as soon as the job is complete.

A new Geophysical Monograph Board has been established under the chairmanship of Alan H. Shapley.

I urge you again to watch the minutes of the Executive Committee and Special Announcements in the *Transactions* for detailed word on these and other developments.

A. NELSON SATRE, General Secretary

REPORT OF THE PRESIDENT

President Ewing noted that he felt the impact of the International Geophysical Year on the AGU has been very great and favorable, and that the Union has been able to adjust its affairs to accommodate the increased demands made by the IGY. He expressed gratification at the increase of our publication program and stressed the need of additional advertising and corporation memberships. He hoped that the members of the Union would take every opportunity to increase this type of participation.

REPORT OF STANDING COMMITTEE

Meetings—Chairman P. H. Abelson noted that it is the tentative plan of the American Physical Society to set its meeting dates for 1960 to coincide with those of the National Academy of Sciences, and that our next annual meeting should be held on Thursday, Friday, and Saturday, April 28-30, 1960. President Ewing reported the registered attendance of the annual meeting just concluded as 1425, probably the best attendance of any meeting thus far. He also noted that the Union owes Chairman Abelson a special vote of thanks for arranging the excellent program and taking care of other arrangements for the meeting.

REPORTS OF SPECIAL COMMITTEES

Tellers—Chairman James N. Jordan reported concerning the elections held by mail ballot during March 1959. The Committee met on April 10, 1959, and tallied ballots as follows:

Total ballots received	2060
Rejected ballots	
Ballots received late (April 6, 1959)	2
Ballots from non-citizens of the United States	8
Defective ballots (unmarked, unsigned, or intent of voter not clear)	3
Ballots from student members	4
Ballots from delinquent members	7
Qualified ballots tabulated	2036

Ballots received from Pacific Northwest Region	121
Ballots received from Pacific Southwest Region	300
Ballots received from North Central Region	85

The following officers were elected for the triennium July 1, 1959 to June 30, 1962:

Officers of the Union

President	LOYD V. BEEKNER
Vice President	F. W. REICHELDERFER
General Secretary	A. NELSON SATRE

Section of Geodesy

President	CHARLES PIERCE
Vice President	FLLOYD W. HOUGH
Secretary	BURFORD K. MEADE

Section of Seismology

President	L. M. MURPHY
Vice President	J. A. PEOPLES, JR.
Secretary	B. F. HOWELL, JR.

Section of Meteorology

President	THOMAS F. MALONE
Vice President	GORDON E. DUNN
Secretary	WOODROW C. JACOBS

Section of Geomagnetism and Aeronomy

President	LEROY R. ALLREDGE
Vice President	C. T. ELVEY
Secretary	J. HUGH NELSON

Section of Oceanography

President	WALTER H. MUNK
Vice President	D. W. PRITCHARD
Secretary	EUGENE C. LA FOND

Section of Volcanology, Geochemistry, and Petrology

President	ALFRED O. C. NIER
Vice President	FRANCIS J. TURNER
Secretary	IRVING W. FRIEDMAN

Section of Hydrology

President	WALTER B. LANGBEIN
Vice President	WILLIAM C. ACKERMAN
Secretary	CHARLES C. McDONALD

Section of Tectonophysics

President	PATRICK M. HURLEY
Vice President	L. B. SLICHTER
Secretary	H. RICHARD GAULT

Members of Executive Committee of Section:

CLARENCE R. ALLEN
IRIS BORG

The following candidates were elected to the Committee of the North Central Region: Rudolph A. Black, Harry C. Bolon, Wayne L. Decker, Joseph W. Howe, Philip W. Kenworthy, Martin E. Nelson, Robert J. Pafford, Jr., Robert H. Shaw, and Athelstan F. Spilhaus.

The following candidates were elected to the Committee of the Pacific Southwest Region: Representing Hydrology—Arthur F. Pillsbury, Joseph F. Poland, and David K. Todd; representing Oceanography—Henry W. Menard and Jacob B. Wickham; representing Meteorology—W. D. Dutchie, Eugene Bollay, and Robert E. Holser; representing Geomagnetism and Aeronomy—E. H. Vestine.

The following candidates were elected to the Committee of the Pacific Northwest Region: Representing Geodesy—Ector B. Latham; representing Seismology and Tectonophysics—Mark F. Meier; representing Meteorology—Donald W. Kuehl and Melvin J. Ord; representing Geomagnetism and Aeronomy, and Volcanology, Geochemistry and Petrology—Keith B. Anderson; representing Oceanography, Ned Bethlahmy; representing Hydrology—Calvin C. Warnick, Thomas H. Campbell, and Albert M. Moore.

In each case there was a simple majority, and the one receiving this majority was deemed to be elected, the exception being in the case of the Pacific Northwest Region as noted above. It was moved by Chairman Jordan, seconded, and accepted that in the event that an office has only one candidate, it is unnecessary for the Committee of Tellers to tally the ballots.

The Special Committee of Tellers, appointed by President Ewing upon nomination of the Section officers, was as follows: James N. Jordan, Chairman; Leslie F. Bailey, Norman F. Braaten, P. Edward Byerly, Bernard C. Byrnes, Dayton E. Carritt, Sydney P. Clark, Jr., George W. Cry, William J. Dempsey, L. P. Disney, Gilbert H. Espenshade, Robert B. Gillou, Charles S. Gilman, Richard S. Goodridge, Roland G. Henderson, J. W. Joyce, Elizabeth R. King, Ralph F. Kresge, Harold F. Morey, V. S. Murino, Boyd E. Olson, Hyman Orlin, A. Delbert Peterson, W. D. Potter, R. W. Seaton, William C. Spreen, Harris B. Stewart, Jr., George R. Tilton, A. C. Turnock, and Bernard D. Zetler.

Cosmic-Terrestrial Relationships—In the absence of Chairman E. H. Vestine, Vice Chairman Walter Orr Roberts presented the report of the Committee in summary, which was accepted, and will be published with the minutes of the Executive Committee in the September issue of the *Transactions*.

Resolutions—In the absence of Chairman John N. Adkins, Norman Haskell presented the following resolution submitted by the AGU Special Committee for the Study of the Metric System in the United States (Floyd W. Hough, Chairman):

(1) RESOLUTION ON THE ADOPTION OF THE METRIC SYSTEM IN THE UNITED STATES

WHEREAS, Scientists and engineers are generally agreed that the Metric System of Weights and Measures is far superior to the English System in the ease of learning and of application to everyday uses, and

WHEREAS, The United States is among the ten per cent of the people of the world not living under the metric system, thus suffering more and more in world trade and other international contacts, and

WHEREAS, The meter and the kilogram are the legal standards of length and mass in the United States, to which are referred the English units, and

WHEREAS, The current rapid strides in science

and engineering seem to urge appropriate action in this regard with a transition period of sufficient length to avoid disruption in the economy, therefore be it

RESOLVED, That the American Geophysical Union urges the adoption of the Metric System as the only official system of Weights and Measures in the United States, effective one generation of 33 years subsequent to the passage of appropriate legislation by the Congress.

There was some discussion of this resolution, after which it was unanimously adopted.

In addition, the following resolutions of thanks were unanimously adopted:

(2) RESOLUTION OF THANKS FOR THE USE OF FACILITIES

WHEREAS, The success of the Pacific Southwest Regional Meeting at Stanford, California, February 5-6, 1959, was due in large part to the space and facilities generously provided by Stanford University, therefore be it

RESOLVED, That the thanks of the American Geophysical Union be extended to Stanford University for the use of their meeting rooms and other facilities, and that the General Secretary be instructed to forward a copy of this resolution to the appropriate official of Stanford University.

(3) RESOLUTION OF THANKS FOR THE USE OF FACILITIES

WHEREAS, The District of Columbia Chapter of the American Red Cross has provided the use of its Auditorium for the Fortieth Annual Meeting of the American Geophysical Union, therefore be it

RESOLVED, That the American Geophysical Union express its great appreciation of this cooperation and instruct the General Secretary to express the thanks of the Union to the appropriate official.

(4) RESOLUTION OF THANKS FOR THE USE OF FACILITIES

WHEREAS, The National Academy of Sciences has provided the use of meeting rooms and other services for the Fortieth Annual Meeting of the American Geophysical Union, therefore be it

RESOLVED, That the American Geophysical Union express its great appreciation of this cooperation, extended over many years, and instruct the General Secretary to express the thanks of the Union to the appropriate official.

(5) RESOLUTION OF THANKS FOR THE USE OF FACILITIES

WHEREAS, The United States Public Buildings Administration has provided the use of a meeting room and other services for the Fortieth Annual Meeting of the American Geophysical Union, therefore be it

RESOLVED, That the American Geophysical Union express its great appreciation of this cooperation, extended over many years, and instruct the General Secretary to express the thanks of the Union to the appropriate official.

(6) RESOLUTION OF THANKS FOR THE USE OF FACILITIES

WHEREAS, The National Science Foundation has

provided the use of its Auditorium for the Fortieth Annual Meeting of the American Geophysical Union, therefore be it

RESOLVED, That the American Geophysical Union express its great appreciation of this cooperation and instruct the General Secretary to express the thanks of the Union to the appropriate official.

(7) RESOLUTION OF THANKS FOR THE USE OF FACILITIES

WHEREAS, The Department of State has provided the use of its Auditorium for the Fortieth Annual Meeting of the American Geophysical Union, therefore be it

RESOLVED, That the American Geophysical Union express its great appreciation of this cooperation and instruct the General Secretary to express the thanks of the Union to the appropriate official.

The telegram of invitation to AGU members from President W. W. K. Warren of the International Petroleum Exhibition in Tulsa, May 14-23, 1959, was read.

President Ewing noted he would like to thank the officers of the Union and of the Sections, as well as the various Committees, for the cordial cooperation he received during the time he has

held the office of President. He then turned the chair over to President-Elect Berkner.

President-Elect Berkner noted that when he becomes President on July 1, 1959, it would be difficult to take over an organization that is in such good shape as the AGU, financially and otherwise. He noted that there are international plans for the generation of future international cooperation in various fields of geophysics. He spoke favorably regarding our publications commenting that Alan H. Shapley, Chairman of the new Monograph Board, had held the first meeting of the Board on May 6, and that plans are being formulated to provide for the future of the Monograph Series. Internationally, our important task in the next three years is to join with the International Union of Geodesy and Geophysics in every way possible to help advance its objectives. During the next few months detailed plans will be laid for our effective participation in the next General Assembly of the IUGG which will be in Helsinki, Finland, July 25-August 6, 1960.

Adjournment—The Business Meeting adjourned at 16h 35m.

A. NELSON SAYRE, *General Secretary*
WALDO E. SMITH, *Executive Secretary*

APPENDIX A—Minutes of the Annual Meeting of 1959, Section of Geodesy, American Geophysical Union

President Schmidt called the meeting to order in the Great Hall, National Academy of Sciences at 09h 15m on May 4, 1959. He announced the results of the election of officers of the Section for the next triennium (see Tellers' Report above). No business was transacted.

The scientific session proceeded with the reading of the following papers:

- (1) WILLIAM MARKOWITZ: The Dual-Rate Satellite
- (2) WERNER D. KAHN: Determination of Correction to Mark II Minitrack Station Coordinates from Artificial Satellite Observations
- (3) W. M. KAULA: A Statistical and Harmonic Analysis of Gravity
- (4) J. A. O'KEEFE, D. ANN ECKELS, AND R. KENNETH SQUIRES: Zonal Harmonics of the Earth's Field and the Basic Hypothesis of Geodesy
- (5) GEORGE VEIS: Geodetic Connections with Artificial Satellites

The session recessed at 11h 46m and reassembled at 14h 00m with Frank L. Culley, the outgoing secretary, presiding. The following papers were presented:

- (6) LLOYD G. D. THOMSON AND LUCIEN J. B. LACOSTE: Airborne Gravity Measurements
- (7) H. ORLIN: The Three Components of the External Anomalous Gravity Field
- (8) JOHN C. ROSE AND G. P. WOOLLARD: The Accuracy of Gulf-Wisconsin Pendulum Results
- (9) JAMES B. SMALL: Settlement Investigations in the Vicinity of Galveston-Houston, Texas, and San Joaquin Valley, California
- (10) N. A. OSTENSO, E. THIEL, G. P. WOOLLARD, AND W. E. BONINI: Gravity Measurements in Alaska
- (11) ERIK TENGSTRÖM: On the Practical Solution of the Boundary Value Problem of Physical Geodesy

The meeting adjourned at 17h 05m.

FRANK L. CULLEY, *Secretary*

APPENDIX B—Minutes of the Annual Meeting of 1959, Section of Seismology, American Geophysical Union

Vice President Murphy opened the Fortieth Annual Meeting of the Section of Seismology with a brief business session at 14h 00m, May 4, 1959. The minutes of the Thirty-Ninth Annual Meeting were approved as published (*Trans.*, 39,

559, 1958). Vice President Murphy reported as a committee member that it was not feasible to arrange a joint meeting with the Eastern Section of the Seismological Society of America.

Announcement was made of the officers elected

to serve during the triennium beginning July 1, 1959 (see Tellers' Report above).

The business meeting was adjourned, and the following papers were presented at the scientific sessions.

- (1) FREEMAN GILBERT AND GORDON J. F. MACDONALD: Free Oscillations of the Earth
- (2) H. BENIOFF, J. C. HARRISON, W. H. MUNK, AND L. B. SLICHTER: A Search for the Free Oscillations
- (3) FREEMAN GILBERT AND LEON KNOPOFF: Scattering of P Waves by the Core of the Earth
- (4) LEON KNOPOFF AND GORDON J. F. MACDONALD: An Equation of State for the Earth's Core
- (5) FRANK PRESS: New Results on Mantle and Crustal Structure
- (6) JAMES DORMAN: Theory and Computation of Properties of Surface Waves on Layered Media

Tuesday, May 5, 1959, 09h 00m, Great Hall,
National Academy of Sciences

- (7) J. A. PEOPLES, JR.: A Station Seismograph Calibration System
- (8) JOSEPH H. ROSENBAUM: The Long-Time Response of a Layered Elastic Medium to Explosive Sound
- (9) M. LANDISMAN, Y. SATO, AND M. EWING: Surface Wave Dispersion in Elastic Media Having Gradients in Their Physical Properties
- (10) C. H. DIX: The Reflected Seismic Pulse
- (11) WENCESLAS S. JARDETSKY: Velocity of Prop-

agation of a Disturbance in a Heterogeneous Medium

- (12) JAMES M. BRUNE, JOHN E. NAPE, AND JACK E. OLIVER: A Simplified Method for the Analysis and Synthesis of Dispersed Wave Trains
- (13) PAUL POMEROY: Background and Storm Microseisms in the Period Range 11-22 Seconds
- (14) GERALD R. MACCARTHY: Some First Motions as Recorded at Chapel Hill, N. C.

Tuesday, May 5, 1959, 09h 00m, Great Hall,
National Academy of Sciences

- (15) ELIZABETH T. BUNCE, ROBERT A. PEPINNEY, AND ROBERT N. POOLEY: Seismic Refraction Observations in Buzzards Bay, Massachusetts
 - (16) A. P. CRARY: Seismic Methods and Preliminary Results, Ross Ice Shelf and Victoria Plateau
 - (17) CHARLES R. BENTLEY: Seismic Methods and Preliminary Results, Byrd Land
 - (18) E. THIEL AND N. A. OSTENSO: Airborne Geophysical Studies in Antarctica
 - (19) J. CL. DE BREMAECKER: Seismicity of the West African Rift Valley
 - (20) J. CL. DE BREMAECKER: Electronic Transducer and Tiltmeter
 - (21) GEORGE SUTTON AND JACK E. OLIVER: Seismographs of High Magnification and Long Periods
 - (22) ANATOL J. SHNEIDEROV: Microseisms Due to Magnetostriction and Electrostriction in Some Ferrous and Polarized Rock Deposits
- J. A. PEOPLES, JR., Secretary

APPENDIX C—Minutes of the Annual Meeting of 1959, Section of Meteorology, American Geophysical Union

The Fortieth Annual Business Meeting of the Section of Meteorology was called to order by President Landsberg at 09h 00m, May 4, 1959, in the Auditorium of the American Red Cross Building.

The minutes of the Thirty-Ninth Annual Meeting were approved as published (*Trans.*, 39, 560-562, 1958).

A report was given by the tellers on the election of officers for the next triennium (see Tellers' Report above).

The Chairman of the Cloud Physics Committee, Helmut Weickmann, reported on plans for a Symposium on the Physics of Precipitation to be held at Woods Hole, Massachusetts, June 3-5, 1959.

There being no further business, the annual business session was adjourned at 09h 20m.

The scientific sessions, held jointly with the American Meteorological Society, consisted of the papers listed in the following program.

Monday, May 4, 1959, 09h 00m, Auditorium,
D. C. Chapter, American Red Cross

Cloud Physics (G. D. Kinzer, Chairman)

- (1) M. BROOK AND N. KITAGAWA: An Interpretation of the Ratio of Cloud to Cloud-to-Ground Lightning Discharges
- (2) N. KITAGAWA AND N. BROOK: Similarities and Differences between Cloud-to-Ground and Intracloud Lightning Discharges
- (3) W. E. COBB, B. B. PHILLIPS, AND P. A. ALLEE: Mountain-Top Measurements of Atmospheric Electricity in Northwestern United States
- (4) CHARLES B. MOORE AND BERNARD VONNEGUT: Some Observations of an Association between the Arrival of Rain and the Electrical Potential Gradient on Mt. Withington, New Mexico
- (5) BERNARD VONNEGUT AND CHARLES B. MOORE: Measurement of Electric Fields in the Atmosphere

- (6) R. E. HALLGREN AND C. L. HOSLER: Collection Efficiency of an Ice Pellet in an Ice-Crystal Cloud

Monday, May 4, 1959, 14h 00m, Auditorium,
D. C. Chapter, American Red Cross

Symposium on Satellite Meteorology (Sigmund Fritz, Chairman)

- (7) WILLIS L. WEBB: Application of Available Meteorological Missiles
(8) S. M. GREENFIELD AND W. W. KELLOGG: Spectral Measurements from a Meteorological Satellite
(9) VERNER E. SUOMI AND DAVID S. JOHNSON: Satellites and Rockets
(10) WILLIAM K. WIDGER, JR.: The Processing and Analysis of Satellite Weather Data

Tuesday, May 5, 1959, 09h 00m, Auditorium,
D. C. Chapter, American Red Cross

Radar and Meso-Scale Meteorology (R. Tarble, Chairman)

- (11) L. F. CONOVER AND H. V. SENN: Use of Spiral Overlays in Tracking Hurricanes by Radar
(12) ALEXANDER SADOWSKI: Use of Coastal Radars in Hurricane Forecasting
(13) ROBERT SOURBEER, R. CECIL GENTRY, AND L. F. CONOVER: January 21, 1957, Storm in Southern Florida
(14) TETSUYA FUJITA: Technique of Computing Hurricane Echo Velocity by the Use of Airborne Radar
(15) ALEXANDER SADOWSKI: Use of Radar in Tornado Warnings
(16) TETSUYA FUJITA: Preliminary Report on the Development of Animated Motion Picture in Mesometeorology
(17) STAFF, NATIONAL HURRICANE RESEARCH PROJECT: The Structure of Hurricane Cleo (Time Lapse Radar Movie)
(18) STAFF, NATIONAL HURRICANE RESEARCH PROJECT: Quantitative Analysis of Radar Data from Hurricane Cleo
(19) STAFF, NATIONAL HURRICANE RESEARCH PROJECT: Analysis of Fields of Motion, Temperature, Pressure, and Humidity, Hurricane Cleo

Tuesday, May 5, 1959, 14h 00m, Auditorium,
D. C. Chapter, American Red Cross

Symposium on Bioclimatology (Konrad J. K. Buettner, Chairman)

- (20) H. E. LANDSBERG: Bioclimatic Work in the Weather Bureau
(21) DOUGLAS H. K. LEE: Role of Bioclimatology in the Armed Forces
(22) FREDERICK SARGENT, II: Changes in Ideas on Climatic Origin of Disease
(23) JAMES B. HARRINGTON, JR. AND A. NELSON

DINGLE: The Emission and Dispersion of Ragweed Pollen

- (24) IGHO H. KORNBLUH: Electric Space Charges and Human Health
(25) NICHOLAS E. MANOS: Weather in Public Health Research
(26) K. E. SCHAEFFER: Condensation Droplets and Ionization Pattern in Submarine Atmosphere
(27) KONRAD J. K. BUETTNER: How Good or Bad is Weather for Normal and Sick People

Wednesday, May 6, 1959, Session A, 09h 00m,
Great Hall, National Academy of Sciences

Numerical Session (Theory) and Information Retrieval (Fred G. Shuman, Chairman)

- (28) FRANK LEWIS: Short-Range Terminal Forecasting by a Non-Linear Statistical Model
(29) PHILIP F. CLAAPP: Preferred Levels for Application of Single-Parameter Numerical Prediction Models
(30) BARRY SALTEMAN: On the Maintenance of the Large-Scale Quasi-Permanent Disturbances in the Atmosphere
(31) DOUGLAS K. LILLY: On the Theory of Disturbances in a Conditionally Unstable Atmosphere
(32) S. MANABE: On the Energy Exchange between Polar Continental Air and the Sea of Japan in Winter
(33) LOUIS P. CARSTENSEN AND PAUL M. WOLFF: Experiments in Numerical Prediction Using Synoptic-Empirical Approximations
(34) JOHN SHERROD: Documentation in Meteorology

Wednesday, May 6, 1959, Session B, 09h 00m,
Lecture Room, National Academy of Sciences
Instruments and Refractive Index (Christos Harmanos, Chairman)

- (35) ROBERT M. BROWN: An Automatic Meteorological Data Collecting System
(36) J. B. HARRINGTON AND G. C. GILL: The Flag Sampler: A High Efficiency Sampler for Particles 10 to 100 Microns in Diameter
(37) RAYMOND BELLUCCI: Drag Cord Anemometer
(38) D. P. KELLY AND S. G. MILLEN: An Airborne Cloud-Drop-Size Distribution Meter
(39) FRANK E. JONES AND ARNOLD WEXLER: A Barium Fluoride Humidity Element

Refractive Index

- (40) J. H. MEYER, J. R. BAUER, AND F. A. WILSON: Aircraft Investigations of the Mesometeorological Structure in the Lower Troposphere
(41) B. R. BEAN, L. P. RIGGS, AND J. D. HORN: A Study of the Three-Dimensional Distribution of the Radio Refractive Index
(42) B. R. BEAN AND L. P. RIGGS: On the Synoptic Variation of the Radio Refractive Index

Thursday, May 7, 1959, Session A, 09h 00m,
Great Hall, National Academy of Sciences

Synoptic Meteorology (A. K. SHOWALTER, Chairman)

- (43) H. RIEHL AND J. MIHALJAN: Analysis of the Layer of Maximum Wind
- (44) W. J. SAUCIER: Structures of Jet Streams as Determined from Project Jet Stream Data
- (45) J. K. ANGELL: Use of Transosonde Data as an Aid to Analysis and Forecasting During the Winter of 1958-1959
- (46) ARIE GAALSWYK: Vertical Motions in a Thunderstorm Cell Indicated by a Balloon Flight Incident
- (47) WALTER H. HOECKER, JR.: Wind-Speed Measurements in the Dallas Tornado
- (48) WILLIAM J. EVANS: Meeting the Weather Communications Requirements of Jet Age Aviation

Thursday, May 7, 1959, Session B, 09 00m,
Lecture Room, National Academy of Sciences

General Session (Glen W. Brier, Chairman)

- (49) MARVIN N. HUNTER: The Correlation of the Zurich Sunspot Numbers with the Verification of Aviation Terminal Forecasts
- (50) KONRAD J. K. BUETTNER AND NORMAN THYER: The Anti-Mountain and Anti-Valley Wind
- (51) KENNETH W. SMITH AND ROBERT G. ALLEN: Forecasting the Intensity and Duration of Low-Level Temperature Inversions in a Valley
- (52) V. A. MYERS AND WILLIAM MALKIN: Why is the Hurricane Surface-Wind Field Asymmetrical
- (53) ALFRED K. BLACKADAR AND ABRAHAM B. BERNSTEIN: The Effect of a Horizontal Temperature Gradient on the Surface Wind
- (54) PAUL FRENZEN: Laboratory Studies of Turbulent Diffusion in Stratified Fluids

Thursday, May 7, 1959, Session A, 14h 00m,
Great Hall, National Academy of Sciences

Numerical Weather Prediction (Applications) (G. D. Good, Chairman)

- (55) G. ARNASON: A Report on a New Numerical Weather Prediction's Group
- (56) VINCENT J. OLIVER: Some Applications of Vorticity Advection Charts to Weather Forecasting
- (57) PAUL M. WOLFF, D. W. McILHENNY, AND R. E. WALKER: Verification of JNWP Hurricane Forecasts from 1958
- (58) WILLIAM H. KLEIN, BILLY M. LEWIS, ISADORE ENGER, AND CURTIS W. CROCKETT: Application of Numerical Prognostic Contour Patterns to Surface-Temperature Forecasts
- (59) W. BRUCE RAMSAY: The Use of Numerical Weather Forecasts for Radioactive-Fallout Predictions
- (60) JAMES E. CASKEY, JR., FRED D. WHITE, HAROLD HARSHBARGER, AND FORREST R. MILLER: Navigation Flight Planning by Electronic Computer
- (61) A. ARNOLD AND M. LOWENTHAL: Evaluation of Radiosonde Flights Using IBM 650 Computer

Thursday, May 7, 1959, Session B, 14h 00m,
Lecture Room, National Academy of Sciences
Climatological Analysis (G. W. Moxon, Chairman)

- (62) E. M. FRISBY: A Study of the Vertical Gradient of Temperature near the Ground at a Site in Southeastern South Dakota
- (63) F. POOLER, JR.: A Prediction Model of Mean Urban Pollution for Use with Standard Wind Roses
- (64) D. BRUCE TURNER: A Simple Diffusion Model for an Urban Area
- (65) ROLF M. NILSESTUEN: Estimating Wet Bulb Distribution
- (66) HENRY A. SARMELA: Accuracy of Mean Monthly Geostrophic Wind Vectors as a Function of Station Network Density
- (67) C. I. JACKSON: Meteorological Observations in Ellsmere Island during the International Geophysical Year
- (68) KIRBY J. HANSON: Radiation Measurement on the South Polar Snowfield, A Preliminary Report

WOODROW C. JACOBS, Secretary

APPENDIX D—Minutes of the Annual Meeting of 1959, Section of Geomagnetism And Aeronomy, American Geophysical Union

The Fortieth Annual Meeting of the Section of Geomagnetism and Aeronomy was called to order by Vice President L. R. Aildredge at 09h 00m, May 4, 1959, in the Reading Room, National Academy of Sciences. There were approximately 100 members of the Section in attendance. The minutes of the 1958 meeting were approved as published (*Trans.*, 39, 562, 1959).

Vice President Aildredge announced that there would be a Symposium on Geomagnetism at Co-

penhagen approximately one week prior to the Helsinki meeting of the IUGG in 1960.

Upon announcing that the *Journal of Geophysical Research* would no longer carry the Geomagnetic and Solar Data, some 70% of the membership present indicated that they wanted the publication of this data continued as in the past. After contacting the Editors of the Journal, it was determined that they would continue this publication if the data were submitted by a responsible

organization in a form that could be published without editing.

The results of the recent election were announced (see Tellers' Report above). After other routine announcements the scientific program listed below was presented.

- (1) V. P. HESSLER* AND E. M. WESCOTT: Earth-Current Rapid Fluctuations at College, Alaska
- (2) J. C. CAIN: A Preliminary Study of IGY Magnetic Data from Alaskan Observatories
- (3) S. MATSUSHITA: Geomagnetic Studies with IGY Data from Seven U. S. Stations
- (4) E. J. CHERNOSKY: The Effect of Magnetic Disturbance upon Subsequent Disturbance
- (5) E. MAPLE: Sub-Audio-Frequency Geomagnetic Fluctuations, IGY Project 3.10
- (6) E. H. VESTINE* AND W. L. SIBLEY: Lines of Force of the Geomagnetic Field in Space
- (7) A. J. ZMUDA: Preliminary Results on Some Hydromagnetic Effects Related to the Geomagnetic Field

Tuesday, May 5, 1959, 09h 00m, Reading Room, National Academy of Sciences

- (8) W. B. MURCHAY: Some Properties of the Luminous Aurora as Measured by a Photo-Electric Photometer
- (9) MARTIN HERTZBERG: Ion-Atom Interchange

as an Important Source of Ionospheric Atomic Nitrogen

- (10) FRANCIS S. JOHNSON: The Distribution of Ions above the F-2 Region
- (11) CHARLES COX: Electric and Magnetic Effects of Ocean Tides
- (12) A. J. DESSLER: Effect of Magnetic Anomaly on Particle Radiation Trapped in the Geomagnetic Field
- (13) A. J. DESSLER* AND E. N. PARKER: A Theory of the Geomagnetic Storms
- (14) S. MATSUSHITA: On Artificial Geomagnetic and Ionospheric Storms Associated with High Altitude Explosions
- (15) B. HULTQVIST, J. AARONS* AND J. ORTNER: Effects of the Solar Flares of July 7, 1958 Observed at Kiruna Geophysical Observatory, Sweden
- (16) A. J. ZMUDA: Some Characteristics of the Upper-Air Magnetic Field and Ionospheric Currents
- (17) C. O. HINES: Does the Polar Ionosphere Rotate with the Earth?

During both of the scientific sessions there was active informal discussion from the floor following the presentation of each paper. The meeting was adjourned at 12h 30m.

R. E. GERHARDT, Secretary

* Denotes speaker.

APPENDIX E—Minutes of the Annual Meeting of 1959, Section of Oceanography, American Geophysical Union

The annual meeting of the section was called to order at 09h 15m, May 5, 1959 in the Auditorium of the National Science Foundation by D. W. Pritchard, Secretary, since the President, Roger Revelle, had been delayed. The President arrived shortly thereafter to preside at the conclusion of the business meeting and to serve as chairman of the morning's scientific session. There were 87 members and guests of the section in attendance.

Since no corrections had been received or were made from the floor, the minutes of the thirty-ninth meeting were approved as published (*Trans.*, 39, 562, 1958).

Announcements were made relating to discussions of the Executive Committee concerning closer relations of AGU with IUGG and regarding the appointment of a Geophysical Monograph Board. Those in attendance were reminded of the International Oceanographic Congress to be held in early September 1959 at the United Nations Building, New York.

New officers for the section for the next three years were announced by the secretary (see Tellers' Report above).

The business meeting was then adjourned and the scientific sessions began. The following papers were presented.

- (1) DONALD P. MARTINEAU: The Gulf Stream as an Equivalent-Barotropic System
- (2) GERHARD NEUMANN: On the Dynamical Structure of the Gulf Stream as an Equivalent-Barotropic Flow
- (3) H. B. STEWART, JR., G. G. SALSMAN, AND A. J. GOODHEART: Surface and Subsurface Rotary Currents Measured at the Outer Edge of the Continental Shelf
- (4) DONALD R. F. HARLEMAN AND JAN M. JORDAAN, JR.: Density Effects on Time-Dependent Turbulent Diffusion in an Idealized Estuary
- (5) D. W. PRITCHARD: A Test of Mixing Length Theories of Vertical Diffusion in an Estuary and in a Pacific Atoll Lagoon

Tuesday, May 5, 1959, 14h 00m, Auditorium, National Science Foundation

- (6) J. E. CHAPPELEAR: A Class of Three-Dimensional Shallow-Water Waves
- (7) BRUCE L. HICKS: The Spectrum of Small Wind Waves
- (8) WILLARD J. PIERSON, JR.: A Note on the Growth of the Spectrum of Wind-Generated Gravity Waves as Determined by Non-Linear Considerations

- (9) TAKASHI ICHIYE: A Theory of Storm Surges on the Continental Shelf
- (10) WILLIAM L. DONN AND WILLIAM T. MCGUINNESS: North Atlantic IGY Ocean-Wave Results
- (11) WILLIAM T. MCGUINNESS AND WILLIAM L. DONN: Long-Period Ocean Waves at Bermuda

Wednesday, May 6, 1959, 09h 00m, Reading Room, National Academy of Sciences

- (12) GUY FRANCESCHINI: Observations of Radiative Energy Flux Over the Gulf of Mexico
- (13) TAKASHI ICHIYE: Circulation and Water

- Mass Distribution in the Gulf of Mexico
- (14) E. R. IBERT AND DONALD W. HOOD: A Multistage Equilibrator for Use in Measuring the Partial Pressure of Carbon Dioxide in Sea Water
- (15) TARO TAKAHASHI: The Carbon Dioxide Exchange between the North and South Atlantic
- (16) WALLACE S. BROECKER AND EDWIN A. OLSON: Variations in Atmospheric Radiocarbon Concentration Over the Last 2000 Years
- (17) D. F. LEIPPER: Glimpses of Oceanology in USSR

APPENDIX F—Minutes of the Annual Meeting of 1959, Section of Volcanology, Geochemistry, and Petrology, American Geophysical Union

The meeting was called to order at 14h 00m by President J. F. Schairer. The announcement of the new officers was made by the President (see Tellers' Report above).

The President announced the action of the Executive Committee of the Union to adopt a resolution recommending the establishment of an International Association of Geochemistry within the IUGG or to in some other manner associate geochemists with this body in a firm way. Dr. Fleischer of the U. S. Geological Survey mentioned the Commission of Geochemistry of the International Union of Pure and Applied Chemistry which will meet with the International Geological Congress in Copenhagen in 1960. Thus it appears that two avenues of contact with Earth scientists may be provided to interested geochemists.

The program followed with the presentation of these papers:

Monday, May 4, 1959, 14h 00m, Auditorium, General Services Building

- (1) AUSTIN LONG, ARNOLD SILVERMAN, AND J. LAURENCE KULP: Precambrian Mineralization of the Coeur d'Alene District, Idaho
- (2) J. F. EVERNDEN, G. H. CURTIS, R. KISTLER, AND J. D. OBRADOVICH: Argon Diffusion in K-Feldspar, Biotite, Glauconite, and Illite
- (3) G. L. WASSERBURG, G. W. WETHERILL, AND L. A. WRIGHT: Ages in the Precambrian of Death Valley, California
- (4) G. W. WETHERILL, G. R. TILTON, G. L. DAVIS, AND C. A. HOPSON: Mineral Ages in the Washington-Baltimore Area
- (5) P. M. HURLEY, W. H. PINSON, R. F. COMMER, AND H. W. FAIRBAIN: Age Study of Lower Paleozoic Glauconites
- (6) HENRY FAUL: Doubts of the Paleozoic Time Scale
- (7) CHARLES E. GRIFFIN AND J. LAURENCE KULP: K-A Ages on the Precambrian Basement of Colorado

- (8) S. S. GOLDBICH, A. O. NIER, J. H. HOFFMAN, AND H. W. KRUEGER: Problems of Early Precambrian Time
- (9) M. OZIMA: A New Technique for K-A Age Determination

Tuesday, May 5, 1959, 09h 00m, Auditorium, General Services Building

- (10) W. W. WHITTAKER, S. VALASTRO, JR., AND MILTON WILLIAMS: The Climatic Factor in the Radiocarbon Content of Woods
- (11) V. RAMA MURTHY AND CLAIRE C. PATTERSON: Isotopic Composition of Lead in Ore and Associated Igneous Minerals in Butte, Montana
- (12) PAUL W. GAST: The Rubidium-Strontium Age of Stone Meteorites
- (13) G. W. REED, K. KIGOSHI, AND ANTHONY TURKEVICH: Ti, Pb, Bi, and U Contents of Meteorites
- (14) E. L. FIREMAN AND J. DEFELICE: Argon-39 and Tritium in Meteorites
- (15) MICHAEL H. CARR AND KARL K. TURKIAN: A Preliminary Report on the Geochemistry of Cobalt
- (16) JOHN W. WINCHESTER: Determination of Potassium in Biotite by Neutron Activation
- (17) JOHN W. WINCHESTER: Trace Element Analysis in Geochemistry by Neutron Activation—Discussion of Sensitivities and Errors
- (18) J. ADLER: Application of X-ray and Electron Probes in Mineralogical Investigations

Tuesday, May 5, 1959, 14h 00m, Auditorium, General Services Building

- (19) F. E. SENFLE AND ARTHUR THORPE: Magnetic Susceptibility of Tektites and Some Terrestrial Glasses
- (20) EDWARD J. ZELLER: Thermoluminescence as an Indicator of Past Climatic Conditions

- (21) F. R. BOYD AND J. L. ENGLAND: Quartz $\rightleftharpoons$ Coesite Transition
- (22) G. C. KENNEDY, G. J. WASSERBURG, AND H. HEARD: The Upper Three-Phase Region in the System $\text{SiO}_2\text{-H}_2\text{O}$
- (23) L. S. WALTER: Determination of the PT Curves for the 'Monticellite' and 'Akermanite' Reactions of Bowen's Decarbonation Series
- (24) P. J. WYLLIE AND O. F. TUTTLE: The Calcite-Portlandite Join in the System $\text{CaO-CO}_2\text{-H}_2\text{O}$
- (25) J. V. SMITH AND W. L. BROWN: Single Crystal X-ray Data on the Polymorphism of MgSiO_3
- (26) WILLIAM L. BROWN: The Existence of Monoclinic Albite at Room Temperature
- (27) DAVID R. WONES: Biotites: Phase Relations of the $\text{K}_2\text{O-6FeO-Fe}_2\text{O}_3\text{-6SiO}_2\text{-2H}_2\text{O}$ End Member
- (28) PETER K. WEYL: Pressure Solution—A Phenomenological Theory
- (29) W. C. KRUMHEIN: Trend Surface Analysis of Contour-Type Maps with Irregular Control-Point Spacing
- (30) E. H. TIMOTHY WHITTEN: Composition Trends in a Granite: Modal Variation and Ghost Stratigraphy in Part of the Donegal Granite, Erie
- (31) A. C. TURNOCK AND H. P. EUGSTER: Subsolidus Relations of Magnetite-Hercynite and Magnetite-Hematite-Corundum Assemblages
- (32) BRADFORD A. HALL AND F. DONALD ECKELMANN: Nature and Petrologic Significance of Gravity Settling in a Dike of Westerly Granodiorite, Bradford, Rhode Island
- (33) LEONARD H. LARSEN AND ARIE POLDERVAART: Contributions to the Petrology of Bald Rock Batholith near Bidwell Bar, California
- (34) WILLARD H. PARSONS, ADRIAN F. RICHARDS, AND JOHN W. MULFORD: Capelinhos Eruption of Fayal Volcano, Azores (including a movie of the eruption)
L. THOMAS ALDRICH, Secretary

Wednesday, May 6, 1959, 09 00m, Auditorium,
General Services Building

APPENDIX G—Minutes of the Annual Meeting of 1959, Section of Hydrology, American Geophysical Union

President Ray K. Linsley called the Business Meeting to order at 09h 10m, May 4, 1959, in the Lecture Room of the National Academy of Sciences.

The President announced the results of the election of officers of the Section of Hydrology (see Tellers' Report above).

President Linsley then announced that upon recommendation of the Hydrology Committee on Awards the paper "Yield of Sediment in Relation to Mean Annual Precipitation," by W. B. Langbein and S. A. Schumm (Dec. 1958) has been selected as the best Hydrology paper to appear in the *Transactions* of 1958 and that this paper is to receive the Horton Award for that year. A certificate of Award will be prepared and forwarded to each author at an early date.

Secretary Wilson announced that since the last meeting the Section had actively participated in a symposium on "Glacier Movement" sponsored by the International Association of Hydrology at Chamonix, France, in September 1958. Announcement was also made of plans completed for U. S. participation in the IAH symposium on "Forests and Waters, and Lysimeters" to be held at Hanover-Munden, Germany, September 1959. A. J. Cooper, Chairman of the Hydrology Research Committee on Surface Water was commended for the excellent job he did in handling arrangements for the Forests and Waters Symposium. Manuscripts of twelve good U. S. papers are in the Secretary's hands ready to be forwarded to Professor Tison of IAH.

The Secretary also announced that plans are underway for U. S. Hydrology participation in the Twelfth General Assembly of IUGG to be held in Helsinki, Finland, July 25-August 6, 1960. A complete outline of these plans will be found in Special Announcements in this issue of the *Transactions*.

President Linsley announced that P. H. Abelson and J. A. Peoples Jr., coeditors of the new *AGU Journal of Geophysical Research*, had graciously accepted an invitation to speak to the section and outline the editorial and publication policies regarding the *Journal*. After brief talks by each of them, the session was opened for questions from the members present.

The Business Meeting then adjourned and was followed immediately by the scientific sessions. The first session, under the Chairmanship of President Linsley, began at 09h 30m and was presented as follows, with 68 members and guests present:

- (1) J. B. STALL* AND L. J. BARTELLI: An Analysis of the Sediment-Producing Character of Watersheds
- (2) A. R. CROFT: The Concept of Erosion Potential of Mountain Land and its Significance
- (3) R. F. HADLEY: The Effect of Waterspreading on Streamflow and Suspended Sediment Discharge (presented by G. C. Parker)
- (4) WALLACE DELAGUNA: The Brookhaven Lysimeter

- (5) FOREST STEARNS* AND C. A. CARLSON: Some Correlations Between Solar Radiation and Other Environmental Factors and Soil Moisture Depletion
- (6) A. W. KRUMBACH: Effects of Microrelief on Soil Moisture Distribution

The second Scientific Session, under the Chairmanship of W. C. Ackermann began at 14h 00m, May 4, 1959, in the Reading Room, National Academy of Sciences. The following program was presented with 77 members and guests present during the course of the session:

- (7) H. D. BURKE AND A. W. KRUMBACH*: Liquid Nitrogen For Sampling Wet Soils
- (8) G. P. LAWLESS AND P. R. NIXON*: Translocation of Moisture with Time in Unsaturated Soil Profiles
- (9) SAM SHULTS: Two Principles of Stability of River Form; Discussant: M. G. Wolman
- (10) W. W. LAMOREUX: Salton Sea Evaporation Study
- (11) W. J. ROBERTS: Reducing Lake Evaporation in the Midwest
- (12) C. H. M. VAN BAVEL: Water Deficits and Irrigation Requirements in the Southern United States
- (13) S. J. URSIC AND J. L. THAMES*: Effect of Cover Types and Soils on Surface Runoff
- (14) J. L. THAMES* AND S. J. URSIC: The Soil Moisture Variable in Surface Runoff Prediction

The third session was called to order by Chairman D. K. Todd, May 5, 1959, at 09h 05m in the Lecture Room, National Academy of Sciences. The session was well attended with 90 members and guests present:

- (15) D. M. HERSHFELD AND W. T. WILSON*: A Comparison of Extreme Rainfall-Depth from Tropical and Nontropical Storms
- (16) D. W. NEWTON: Storms and Floods on Small Areas
- (17) F. H. LARSON AND VINCENT MCKEEVER: Hydrology and the Small Dam
- (18) C. H. HARDISON: Frequency of Seasonal Storage
- (19) D. M. HERSHFELD* AND M. A. KOHLER: An Empirical Appraisal of the Gumbel Extreme-Value Procedure
- (20) J. R. CRIPPEN: Frequency of Deficient Discharge
- (21) A. L. SHARP*, A. E. GIBBS, W. J. OWEN AND B. HARRIS: Application of the Multiple Regression Approach in Evaluating Parameters Affecting Water Yields of River Basins

The fourth session held in the Lecture Room, National Academy of Sciences was called to order at 14h 00m May 5, 1959 by Chairman H. G. Wilm. Approximately 85 members and guests were present during the session.

- (22) H. R. HENRY: Salt Intrusion into Fresh-Water Aquifers
- (23) F. A. KOHOUT: Cyclic Flow of Salt Water in the Biscayne Aquifer of Southeastern Florida
- (24) YONA KAHANOWITZ: Intensification of Groundwater Exploitation in the Coastal Plain of Israel (presented by Martin Jacob)
- (25) H. E. LEGRAND: Problems of Contrasting Ground-Water Media in Consolidated Rocks of Humid Areas
- (26) R. C. CARTER, G. T. ORLOV, W. J. KAUFMAN AND D. K. TODD*: Studies of Helium as a Ground-Water Tracer
- (27) M. S. HANTUSH: Analysis of Data from Pumping Walls near a River
- (28) E. M. BURT: Evaluation of a Formula Used in Predicting Well Performance

The final session under the Chairmanship of A. J. Cooper, began at 09h 00m, May 6, 1959, in the Auditorium, D. C. Chapter of the American Red Cross. The session was well attended by approximately 84 members and guests.

- (29) H. W. ANDERSON, R. M. RICE AND A. J. WEST: Snow in Forest Openings and Forest Stands (Presented by Arnold Court)
- (30) F. A. CAMP: Hydrologic Processes of Snow and Ice at High Altitude
- (31) R. S. SIGAFOOS: Maximum Modern Advance of Nisqually Glacier, Washington, and Its Recession between 1840 and 1900
- (32) L. H. NOBLES: Thermal Regimen of Sub-Polar Glaciers
- (33) PAUL BOCK: Wetted Perimeter and Hydraulic Radius as Parameters in Flow Equations
- (34) R. G. SEMONIN: Artificial Precipitation Potential in Illinois as Inferred from Precipitable Water Data (Presented by W. J. Roberts)

The meeting adjourned at 11h 50m with comments by President Linsley expressing appreciation for the active support of the chairmen and members of the research committees during the last three years, for the work of the Secretary and for the fine assistance of Harry E. Schwarz who at the last minute was appointed Program Chairman and given the job of organizing papers for this meeting.

RALPH N. WILSON, *Secretary*

* Denotes Speaker

**APPENDIX H—Minutes of the Annual Meeting of 1959, Section of Tectonophysics,
American Geophysical Union**

President Hess called the business meeting to order at 09h 10m on May 4 in the General Services Building Auditorium. President Hess reported the officers for the next triennium (see Teller's Report) and changes in the meeting schedule for other sections.

The scientific session began at 09h 13m and consisted of the following papers:

- (1) JINGHWA HSU*: A theory of the Origin of Geosynclines
- (2) IRIS BORG*, JOHN HANDIN, AND D. V. HIGGS: Experimental Deformation of Plagioclase Single Crystals
- (3) JOHN M. CHRISTIE* AND C. B. RALEIGH: Deformation Lamellae in Quartz
- (4) E. C. HANSEN*, I. Y. BORG, AND J. C. MAXWELL: Dynamic Significance of Quartz Lamellae
- (5) JOHN C. JAMIESON* AND A. W. LAWSON: A New Device for High-Pressure X-Ray Studies
- (6) HARRY HUGHES*: The Conductivity Mechanism in the Earth's Mantle
- (7) MANIK TALWANI*, J. LAMAR WORZEL, AND MAURICE EWING: Gravity Anomalies and Crustal Section across the Tonga Trench
- (8) MANIK TALWANI, GEORGE H. SUTTON, AND J. LAMAR WORZEL*: Crustal Sections across the Puerto Rico Trench
- (9) JOHN A. WOOD, JR.*: Petrographic Textures in Chondrites

The session ended at 11h 58m.

B. F. HOWELL, JR., *Secretary*

* Denotes speaker.

AMERICAN GEOPHYSICAL UNION

NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL

Statutes and By Laws

(Originally adopted at organization in 1919 and as amended to April 30, 1959)

PREAMBLE

The American Geophysical Union is hereby established by the National Research Council. It supersedes the "American Section of the proposed International Geophysical Union." The American Geophysical Union is the American National Committee of the International Union of Geodesy and Geophysics and the Executive Committee of the American Geophysical Union is the Committee on Geophysics of the National Research Council.

STATUTES

Article 1: Objects—(a) To assist in carrying out the objects of the International Union of Geodesy and Geophysics, which are: To promote the study of problems concerned with the figure and physics of the Earth; to initiate and coordinate researches which depend upon international cooperation, and to provide for their scientific discussion and publication; and to facilitate special researches.

(b) To promote, coordinate, and facilitate the study of the various branches and interrelationships of geodesy and geophysics in the United States of America, its outlying territories, and the ocean; to provide for scientific discussion, publication, and dissemination of information relative to these fields through its publications.

Article 2: Bequests, Grants, Contributions, and Funds—The Union, upon approval of the National Research Council, may receive bequests, grants, contributions, and funds and may make disbursements therefrom, upon approval of the National Research Council.

Article 3: Membership—The membership of the American Geophysical Union shall be as follows:

(a) **Members**—(1) Those who composed the membership of the "American Section of the proposed International Geophysical Union" on July 1, 1919.

(2) Citizens of the United States of America engaged in geophysical research or its applications, elected by the Executive Committee of the American Geophysical Union.

(3) Nationals of other countries having the same qualifications, elected by the Executive Committee of the Union; these may not vote or be officers of the Union or of its Sections, or delegates of the Union to International Assemblies or Meetings.

Members in good standing for a total of 25 years (or 15 years for members joining before January 1, 1946) shall, following retirement from active professional service because of age or disability and upon written notice to the General Secretary, be extended the complete privileges of membership without further payment of dues. The Executive Committee may also extend these privileges to members for extraordinary services to the Union.

(b) **Members ex officio**—(1) The President of the National Academy of Sciences; the Chairman of the National Research Council; the Chairman of the Section of Geophysics of the National Academy of Sciences; the Chairmen of the following Divisions of the National Research Council: Earth Sciences, Physical Sciences, Chemistry and Chemical Technology, and Biology and Agriculture; and the Director of the Office of International Relations of the National Research Council.

(2) Officers of the International Union of Geodesy and Geophysics and of its Associations who are citizens of the United States of America.

(c) **Corresponding Members**—Nationals of other countries, outstanding in the field of geophysics, elected by the Executive Committee of the American Geophysical Union; they shall not pay dues but shall enjoy the privileges of Members except that they may not vote or be officers of the Union or of its Sections or delegates of the Union at International Assemblies or Meetings.

(d) **Associates**—(1) Citizens of the United States of America other than those eligible for regular membership under Article 3, Sections (a) or (b), whose interest in Geophysics is deemed by the Executive Committee of the Union to warrant their election. Associates shall enjoy the privileges of Members except that they may not be officers of the Union or of the Sections, or be delegates of the Union at International Assemblies or Meetings.

(2) Nationals of other countries having the same qualifications, elected by the Executive Committee of the American Geophysical Union; these may not vote or be officers of the Union or of its Sections, or delegates of the Union to International Assemblies or Meetings.

(e) **Corporation Members**—Corporations and other organizations interested in geophysics, elected by the Executive Committee of the Un-

ion. The designated representative of each such organization shall enjoy the privileges of a Member.

(f) *Student Members*—College and university students elected by the Executive Committee. A certificate signed by an officer or professor of the institution attended shall be submitted annually as qualification. The classification of a student member shall terminate after one year of non-student status, and if judged to be qualified by the Executive Committee, the former student shall be an Associate Member on his own written acceptance. Student members shall be privileged to participate in scientific meetings and receive the *Transactions* of the Union.

Article 4: Sections—The American Geophysical Union shall consist of Sections as follows: (a) Geodesy; (b) Seismology; (c) Meteorology; (d) Geomagnetism and Aeronomy; (e) Oceanography; (f) Volcanology, Geochemistry, and Petrology; (g) Hydrology; (h) Tectonophysics.

Members, Corresponding Members, Associates, and Corporation Members shall designate the Section, or Sections, with which they desire to be affiliated. The function of the Sections, in their respective fields, shall be the promotion of the objects of the American Geophysical Union.

Article 5: Officers of the American Geophysical Union—The officers of the American Geophysical Union shall consist of a President, a Vice President, and a General Secretary, whose terms of office shall expire June 30, 1947, but terms of office effective July 1, 1947, shall be for periods of three years, with the limitation that the President and Vice President shall not be eligible for immediate re-election; in case any office, except that of President, becomes vacant, the Executive Committee of the Union shall designate a successor in office to complete the term. In the case of the death of the President, the Vice President shall automatically become President. These officers shall be elected by mail ballot.

There may also be elected, by mail ballot, an Honorary President whose nomination shall be tentatively approved at a meeting of the Executive Committee, followed by a mail ballot of the entire Executive Committee. A confirming vote of three-fourths of those voting shall be required to place the name on the ballot. This office shall be filled only as a special honor for outstanding service to the Union. It shall be for life without payment of dues.

The General Secretary shall act also as Treasurer and shall receive and disburse all dues, grants, and funds otherwise received as authorized by the Executive Committee of the Union; his accounts shall be audited annually by a Committee on Audit.

The Executive Committee of the Union may employ an Executive Secretary, who shall be directly responsible to the General Secretary.

Article 6: Officers of Sections—The officers of each Section of the American Geophysical Union shall consist of a President, a Vice President, and

a Secretary, whose eligibility and periods of office shall correspond to those of the Union as indicated under Article 5. These officers shall be elected by mail ballot. In case any office becomes vacant the Executive Committee of the Section concerned shall designate a successor in office to complete the term. The President of each Section shall have the power to appoint, with the right to vote, a representative of the Section to such meetings of the Executive Committee of the Union as he may be unable to attend.

Article 7: Executive Committee—The Executive Committee of the Union shall consist of the President, the Vice President, and the General Secretary of the Union, and the President or his designated representative and the Secretary of each Section of the Union, the last past Presidents of the Union and its Sections, the Chairmen of the Standing Committees of the Union; and, in addition, *ex officio*, the Honorary President, the Executive Secretary of the Union, and members *ex officio*, as listed in Article 3 (b) of these Statutes.

This Committee shall have charge of all administrative matters of the American Geophysical Union and shall be the representative of the Union in its relations with the National Research Council and the International Union of Geodesy and Geophysics. It shall have the power to delegate to the Officers and to standing and Special Committees, with power of action and decision, any of its specific functions.

There shall be an Executive Committee of each of the Sections of the Union which shall include at least the President, Vice President, and the Secretary and the last past President of the Section.

Article 8: Annual Meetings—The American Geophysical Union and its Sections shall meet annually at such time and place as may be chosen by the Executive Committee of the Union.

Article 9: Special Meetings—Special Meetings of the American Geophysical Union, of any Section or of any group of Sections, and of any Local or Regional Branch may be called by the respective Presidents with the advice of the respective Executive Committees; notification of such meetings must be communicated promptly to the office of the General Secretary of the Union.

Article 10: Branches of the Union—Local or Regional Branches of the Union may be established on the approval of the Executive Committee of the Union. These Branches shall be organized along the general lines of the Union, shall be responsible to the Executive Committee of the Union, and shall duly report their activities through the General Secretary.

Article 11: Publications—The official publications of the Union shall include the *Transactions of the American Geophysical Union*, *Journal of Geophysical Research*, and the *Geophysical Monograph Series*, published under the auspices of the National Academy of Sciences—National Research Council.

The *Transactions* shall be a regular periodical which contains the reports of Union activities, notes and personalia, special announcements, and other material of a transitory or semi-popular nature. Control of matter to be published in the *Transactions* shall rest in the Executive Secretary with the aid and counsel of the Secretaries of the several Sections.

Journal of Geophysical Research shall be a regular periodical which contains the scientific and technological papers and related departments. Control of matter published in *Journal of Geophysical Research* shall rest in the Editors-in-Chief appointed for indefinite terms by the Executive Committee, and shall have the aid and counsel of an advisory board representing the special fields of geophysics. This board shall be designated by the President in consultation with the Editors-in-Chief and the Executive Committee.

The *Geophysical Monograph Series* will be published as members of the series develop and issues of the series shall be under the control of a special editorial board designated by the President, with the Executive Secretary serving as managing editor of the series.

Other publications that may develop shall be subject to approval by the Executive Committee under plans developed for their editorial management.

Non-members of the Union may subscribe to the *Transactions*, and purchase individual copies thereof, as well as other publications of the Union, at rates approved by the Executive Committee of the Union.

Article 12: By Laws—The American Geophysical Union is authorized to enact such By Laws as may be necessary for the performance of its functions and duties.

Article 13: Amendments—(a) Any Member, Associate, or Corporation Member may propose an amendment to the Statutes. Such proposals shall be considered by the Committee on Statutes and By Laws and presented to the Executive Committee of the Union with recommendations. Upon approval of the Executive Committee, proposed amendments shall be submitted to the membership for a mail vote. Balloting shall be open for not less than 30 days. A majority of the votes cast shall be required for adoption. Amendments shall be subject to the approval of the National Research Council.

(b) Any Member, Associate, or Corporation Member may propose an amendment to the By Laws. Such proposal shall be considered by the Committee on Statutes and By Laws and presented to the Executive Committee of the Union with recommendations. Upon approval of the Executive Committee, proposed amendments shall be published in the *Transactions* not less than 30 days prior to action at a succeeding meeting of the Executive Committee. Action must be completed within a year after publication. Approval by the Executive Committee at this meeting shall constitute adoption of the amendments. An affirm-

ative vote of not less than half the membership of the Executive Committee shall be required for approval.

BY LAWS

(1) The *fiscal year* of the American Geophysical Union shall conform to the fiscal year of the National Research Council.

(2) Members of the Union, in classes (a) and (d) of Article 3 of the Statutes, shall pay dues, the amount for each year to be fixed by the Executive Committee of the Union. Members of class (e) shall pay dues of not less than \$100 for each calendar year. Any Member or Associate, on payment of an amount to be fixed by the Executive Committee of the Union (currently \$200.), shall be relieved of further payment of dues. Members of class (f) shall pay dues approximating the cost of a volume of the *Transactions* plus the cost of a volume of the *Journal of Geophysical Research*, the amount for each year to be fixed by the Executive Committee.

(3) *Standing Committees* shall be as follows: Statutes and By Laws; Membership; Meetings; Nominations; Budget; Audit.

There shall also be a standing Committee on International Participation consisting of the President, the General Secretary, and the Executive Secretary of the American Geophysical Union and six additional persons (not necessarily AGU members) who are eminent geophysicists with knowledge and background in international organization and cooperation. The Committee shall be appointed at the first meeting of the Executive Committee following each Assembly of the IUGG, and shall serve for a term of three years to include the interval of the next Assembly. The Committee, acting on behalf of the Executive Committee, shall (a) recommend to the Office of International Relations, NRC, the organization of delegations to the Assemblies of the IUGG and to such other international meetings as may be appropriate; (b) review all administrative questions that might or should be raised at, or may be related to, international meetings or assemblies with the view of fully informing our delegations of the implications thereof; (c) advise the NRC Foreign Policy Committee, or the NRC Committee on International Unions, on matters of international science policy relating to geophysical science; and (d) advise the Executive Committee of the AGU of all actions taken or initiated. The Committee shall take full account of the broad interests of geophysical science in the United States, and of the various organizations and agencies involved in geophysical activity.

(4) *Special Committees* shall be established from time to time, as need arises, to consider special matters approved by the Executive Committee of the Union.

(5) *Appointments to Committees* of the American Geophysical Union shall be made by the President or President-Elect and appointments shall terminate at the end of the fiscal year for

which they are made, unless otherwise specifically designated; no appointment shall extend, however, beyond the term of office of the appointing President or President-Elect.

(6) *Meetings of the Union* shall be called at least 30 days in advance, and those present at the meeting shall constitute a quorum.

(7) *Meetings of the Executive Committee of the Union* shall be called by the President at least 15 days in advance and a minimum of 12 shall constitute a quorum.

(8) *Final action on matters affecting any Section* specifically shall not be taken by the Executive Committee of the Union when that Section is not represented.

(9) *Statutes and By Laws adopted by a Section or Branch* shall not conflict with the provisions of the Statutes and By Laws of the Union.

(10) *Matters pertaining solely to a Section* and not to the Union as a whole, shall be acted upon by the Section concerned.

(11) No mail ballot of the Union shall be closed until at least 30 days after date of issue.

(12) Officers, designated by the Executive Committee of the Union or the Executive Committee of any of its Sections, to fill *uncompleted terms*, shall not hold office without election after expiration of the period for which their predecessors were elected.

(13) *Removal from the rolls*, other than by resignation, of a Member, Corresponding Member, Associate, or Corporation Member of the American Geophysical Union shall be made only upon a three-fourths vote of a quorum of the Executive Committee of the Union; Members, Associates, and Corporation Members who fail to pay dues for two consecutive years shall be reported to the Executive Committee by the General Secretary with recommendation that their names be removed from the Union's rolls.

(14) Under special circumstances and upon request to the General Secretary any Member or Associate may be transferred to an *Inactive List* of the Union without further payment of dues and without other privileges as Member or Associate but *reinstatement* may be made upon request and payment of current year's dues.

Reelection of Members and Associates who have been dropped from the rolls by action of the Executive Committee of the Union may be effected only after filing a signed application under the usual procedure for election of Members and Associates.

(15) The Executive Committee of the Union may arrange, either through bequests, special contributions, grants, or other funds of the Union, for *awards, medals, honoraria, or certificates of merit* to geophysicists in recognition of meritorious work or service in the field of the whole Union or in the field of any of its several Sections, and for *scholarships, fellowships, or grants-in-aid* to assist worthy candidates in the advancement of geophysical science.

(16) The Executive Committee may appoint

Union or Section representatives to other organizations, upon mutual agreement, when such representation may promote coordination and interest in geophysics. The Executive Committee of the Section concerned shall make tentative arrangements for interorganization-relationships and make selections of representatives of the Sections. Arrangements and commitments must be ratified by the Executive Committee of the Union before they are binding on the Union.

(17) *The duties of the President* shall be those ordinarily appertaining to this office; he shall preside at the meetings of the Executive Committee and at General Meetings of the Union, shall appoint members of Standing and Special Committees. The more important letters, and especially those concerned with policy of the Union, shall be signed by the President or the General Secretary in accordance with rules, precedents, and decisions of the Executive Committee of the Union.

(18) In the absence or in the event of the disability of the President, the Vice President shall carry out the duties ordinarily performed by the President.

(19) The General Secretary elected by the Union shall be responsible to the Executive Committee of the Union for the general administration of the Union's activities as determined by the Executive Committee of the Union. He shall serve without honorarium, and shall exercise general supervision over the Executive Secretary. He shall serve as Treasurer of the Union, receive and disburse funds in accordance with the instructions of the Executive Committee of the Union, sign checks as General Secretary on the accounts of the American Geophysical Union with depositories approved by the Executive Committee of the Union, and shall provide a surety bond in a sum set by the Executive Committee of the Union and at the expense of the Union, for funds of the Union under his control. If the General Secretary is absent or incapacitated, the President, or, if he is absent or incapacitated, the Vice President, shall sign checks against the Union accounts. The General Secretary, or the President or the Vice President serving as Treasurer in his capacity, may empower the Executive Secretary to sign checks against the accounts of the Union during their terms of office. The President, the Vice President, and the Executive Secretary shall furnish surety bonds in the same manner and amount as the General Secretary.

(20) *The Executive Secretary* shall be responsible to the General Secretary and, with the assistance of such clerical help as is necessary, shall perform all executive and other duties as indicated by the General Secretary.

(21) One copy of each issue of (a) the *Transactions*, (b) *Journal of Geophysical Research*, (c) any published *List of Members and Officers*, and (d) any other publication which may be approved for free distribution to the membership by the Executive Committee of the Union, shall be sent to each Member, Associate, and Corporation

Member whose annual dues for the calendar year have been paid by February 15; any person or organization newly elected as Member, Associate, or corporation Member shall be sent without charge one copy of these publications beginning with the calendar year in which elected and for which dues have been paid. Each member on a retired basis, Member ex officio, and Corresponding Member shall be accorded this privilege also. Each Student Member shall receive one copy of

each issue of the *Transactions* and one copy of each issue of the *Journal of Geophysical Research* for each year of paid membership.

Each person and organization in good standing in any class of membership may purchase any available publication of the Union at a discount from the printed price list to non-members. The General Secretary is authorized to establish discounts for sales of publications.

SPECIAL ANNOUNCEMENTS

SYMPOSIUM ON FOREST INFLUENCES IN HYDROLOGY—The International Association of Hydrology will hold a Symposium on Forest Influences in Hanover-Munden, Germany, September 8-12, 1959. The program is now closed and includes twelve papers from the United States. Persons who would like to attend or who desire further information, who are citizens of or in residence in the United States, should write to Ralph N. Wilson (3322 Stanford Drive, University Hills, West Hyattsville, Maryland), who is serving as a clearing house on these matters. Others should get into touch with their respective national committees or with the Secretary of the International Association of Hydrology, L. J. Tison, 61 rue des Ronces, Gentbrugge, Belgium.

PACIFIC NORTHWEST REGIONAL MEETING—Plans are progressing for a Pacific Northwest Regional meeting to be held at Corvallis, Oregon, November 5-6, 1959. Interested persons should get in touch with Wilbur D. Simons (U. S. Geological Survey, 529 Perkins Building, Tacoma 2, Washington), who is Chairman for the current year and is in charge of organizing the Committee for the coming triennium.

PACIFIC SOUTHWEST REGIONAL MEETING—Plans are developing for the Pacific Southwest Regional meeting to be held sometime in late January or early February, 1960, in accordance with past custom. Interested persons should get into touch with the current Chairman, Vito A. Vanoni (California Institute of Technology, 1201 East California Street, Pasadena 4, California), who is in charge of organizing the Committee for the new triennium.

FORTY-FIRST ANNUAL MEETING—The Forty-first Annual Meeting of the American Geophysical Union will be held in Washington, D. C., on the Thursday, Friday, and Saturday following the meeting of the National Academy of Sciences, probably April 28, 29, and 30, 1960. If the National Academy meeting dates are changed from April 25, 26, and 27, 1960, we will adjust our meeting to follow that meeting in the last three days of the week. Watch SPECIAL ANNOUNCEMENTS for further word.

TWELFTH GENERAL ASSEMBLY OF THE IUGG—Plans are developing rapidly for the Twelfth General Assembly of the International Union of Geodesy and Geophysics which will be held in Helsinki, Finland, July 25 to August 6, 1960. Any who plan to attend or any who would like to present papers who are citizens or residents of the

United States should get in touch with the office of the AGU without further delay. The March 1959 issue of the *Transactions*, page 40, contains further information on the subject, and below is given special information as it relates to the Association of Hydrology.

INFORMATION REGARDING PAPERS FOR THE ASSOCIATION OF HYDROLOGY, IUGG TWELFTH GENERAL ASSEMBLY, HELSINKI, FINLAND

Plans have been made by the Executive Committee of the Section of Hydrology calling for early notification by potential authors of Hydrology papers for the 12th General Assembly of IUGG to be held in Helsinki, Finland, July 25—August 6, 1960. The purpose of this notice is to present the list of Hydrology subjects selected by the International Association of Hydrology (IAH) for consideration at the meeting and to provide instructions established by IAH and the Hydrology Executive Committee for submission of information concerning Hydrology papers.

The topics on which papers may be submitted under each of the IAH Commissions and Committees are listed below.

1. *Commission on Snow, Ice and Glaciers*—(No set questions established. Papers related to snow, river and lake ice and glaciology may be submitted.)
2. *Commission on Subterranean Waters*—(The program of U. S. papers under this Commission is complete and no additional papers can be accepted.)
3. *Commission on Surface Waters*—A. Pure hydrology: (1) Study of low flows: (a) Mean annual dry-weather flows; (b) Relation of dry-weather flows to rainless periods, geological character of soils, and temperature (winter dry-weather); (c) Runoff coefficients during periods dry-weather flows. (2) Study of runoff from snow melt, (a) Runoff during the cold season, (b) Runoff during period of snow melt.

B. Hydrometeorology: (1) Drought characteristics—meteorological causes, (2) Frequency of drought occurrence—forecasting, (3) Spatial distribution of drought periods—on a large scale regionally, covering several regions or countries, (4) Droughts throughout history in the latest geological periods—connection between this situation and that of the origin and existence of arid zones.

The above subjects under Hydrometeorology will be discussed in joint symposium with the Association of Meteorology on Wednesday afternoon, July 27, 1960.

C. The Surface Water Commission will participate with the Association of Oceanography in a

joint symposium on the general subject Tidal Portions of Rivers. It is planned for the papers in this joint symposium to illustrate the importance of the subject on the welfare of the communities concerned and its connection with the problems of the ocean.

4. *Commission on Land Erosion*—A. Sediment yield of streams; B. Erosion and chemistry of runoff; C. Mechanism of erosion with special reference to the effects of snow melt; D. Influence of land use and management on erosion.

5. *Committee on Precipitation*—A. Measurement—aerodynamical study; B. Measurement in mountain regions; C. Variability in areal extent and in time; D. Measurement with radar.

6. *Committee on Evaporation and Evapotranspiration*—A. Evaporation from a free water surface, (1) Suppression by use of monomolecular films, (2) Further tests of the energy budget and mass transfer methods for the determination of reservoir evaporation, (3) Relationships between pan and reservoir evaporation.

B. Evapotranspiration, (1) A critical evaluation of the advantages and disadvantages of lysimeter research, (2) Tests of the energy budget and mass transfer methods for the determination of evapotranspiration, (3) Studies of the water balance of catchment areas for short periods of time, (4) Evapotranspiration losses in arid zones, (5) Effects of canalization of rivers upon evaporation and evapotranspiration losses.

Papers may be proposed on any other hydrologic topic as well as those listed.

Procedure—A screening committee will be established within each of the Research Committees of the Section of Hydrology to review the abstracts and papers to assure that the material is of high technical quality and that it represents some of the better U. S. practices in the field of the particular subject. This screening committee will be anonymous and will have full authority to accept or reject any paper.

In order to qualify for acceptance by the Hydrology Committee, all U. S. papers for the Helsinki Assembly, in addition to being of high quality, will adhere to the following:

1. An abstract of not more than 250 words will be submitted to the Chairman of the particular Research Committee concerned with the subject matter. The U. S. Chairmen are listed in a later paragraph of this notice. Deadline date for submission of these abstracts is *October 1, 1969*. No abstracts will be accepted after this date. The abstract should be in triplicate and should clearly indicate the nature of the material to be covered in the paper. In addition to the formal abstract which will be used as an advance notice, graphs and other pertinent information that might help illustrate the points to be covered in the paper, may also be furnished with the abstract, if desired. This supplemental information will be used only by the Screening Committee in evaluating the

paper and will not be published. In view of the fact that the Screening Committee will first judge the merits of a paper essentially on the basis of the abstract, a potentially worthwhile paper may be rejected if the abstract is poorly prepared.

2. Manuscripts of accepted papers will be submitted to the particular Research Chairman not later than *January 1, 1969*. Each paper must be limited to 20 type-written pages, double spaced, including any figures or tables. The original and two copies of the text, summary, charts and tables will be submitted. The material presented in the final paper must conform with the approved abstract or the Screening Committee may reject the paper.

3. A short summary (may be similar to the abstract) will accompany the paper. The summary should be in two languages, English and French, if at all possible. This two-language requirement applies only to the summary.

4. Any clearance of an abstract or paper necessary according to regulations of the author's agency or institution, will be the responsibility of individual authors. The clearance should be secured prior to final submission of the text.

5. To facilitate final publication of papers, illustrations or figures will be submitted as drawings, prepared to an appropriate size consistent with necessary reduction in the final printing. Use of photographic illustrations should be eliminated completely, if possible, or held to an absolute minimum.

6. Authors are encouraged to make arrangements to present their papers in person. It is to the interest of the individual, as well as his agency or institution, to be so represented at international meetings. Authors should indicate when submitting the manuscript (1) whether it is to be presented in person, (2) whether arrangements have been made for presentation by someone else, (3) if it is desired that the Section of Hydrology, AGU, arrange for presentation, and (4) name and address of person to be contacted regarding the paper.

Research Committees, Section of Hydrology—The Research Committees of the Section of Hydrology were reorganized by President R. K. Linsley at the beginning of his term as President of the Section, to conform with respective Commissions and Committees of IAH in order to facilitate closer coordination of international matters. The Research Chairmen listed below have been assigned responsibility for coordinating in their respective fields all U. S. papers for the Helsinki Assembly. These Chairmen should be addressed as follows:

1. *Committee on Snow, Ice and Glaciers*—Prof. O. C. Warnick, Chairman, Committee on Snow, Ice and Glaciers, AGU Section of Hydrology, Department of Civil Engineering, University of Idaho, Moscow, Idaho.

2. *Committee on Groundwater*—Dr. George B.

Maxey, Chairman, Committee on Groundwater, AGU Section of Hydrology, Illinois State Geological Survey, Urbana, Illinois.

3. *Committee on Surface Water*—Mr. Alfred J. Cooper, Chairman, Committee on Surface Water, AGU Section of Hydrology, Tennessee Valley Authority, 701 Union Building, Knoxville, Tennessee.

4. *Committee on Erosion and Sedimentation*—Dr. M. Gordon Wolman, Chairman, Committee on Erosion and Sedimentation, AGU Section of Hydrology, Department of Geography, Johns Hopkins University, Baltimore 18, Maryland.

5. *Committee on Precipitation*—Mr. Floyd A. Huff, Chairman, Committee on Precipitation,

AGU Section of Hydrology, Illinois State Water Survey, Urbana, Illinois.

6. *Committee on Evaporation and Transpiration*—Mr. G. Earl Harbeck, Chairman, committee on Evaporation and Transpiration, AGU Section of Hydrology, U. S. Geological Survey, Denver Federal Center, Building 25, Denver 2, Colorado.

The Secretary will be glad to answer what questions he can regarding plans or general arrangements being made by the Section of Hydrology or by IAH for the Helsinki Assembly.

RALPH N. WILSON, *Secretary*, Section of Hydrology Corps of Engineers, Office, Chief of Engineers, Civil Works, Washington 25, D. C.

NATIONAL ACADEMY OF SCIENCES

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IGY BULLETIN

A monthly survey by the U. S. National Committee for the International Geophysical Year. Established by and part of the National Academy of Sciences, the Committee is responsible for the U. S. International Geophysical Year Program in which several hundred American scientists are participating and many public and private institutions are cooperating.

The Floor of the Arctic Ocean

This report is based on a paper given by Kenneth Hunkins, now of the Geophysics Department, Stanford University, at the IGY Symposium during the 125th Meeting of the American Association for the Advancement of Science, Washington, D. C., December 29-30, 1958.

Among the many IGY scientific programs carried out on Drifting Station Alpha, in the Arctic Ocean, were marine geophysics studies directed by the Lamont Geological Observatory of Columbia University and supported by the Terrestrial Sciences Branch of the Air Force Cambridge Research Center. The studies included seismology, gravimetry, earth magnetism, physical oceanography, and measurement of ice drift and currents.

The drifting station, on a ten-foot-thick ice floe, provided a relatively stable platform for this work, in contrast to the rolling and pitching of a research vessel. Moreover, the slow drift of the floe allowed time for detailed study of the ocean bottom, although the floe's irregular and uncertain course somewhat limited the area of coverage. Between June 8, 1957, when celestial navigation began, and November 1, 1958, when the station was evacuated because of break-up of the floe, the total drift, within an area roughly 300 mi square, was 1830 statute mi (see Fig. 1). The average drift was $3\frac{1}{2}$ mi/day.

This report presents some results of investigations of the Arctic Ocean floor and the upper few feet of underlying sediment. The methods used in these studies were seismic echo soundings, dredge hauls of bottom material, submarine photography, and bottom coring and "grab" sampling.

Topography and Structure of the Bottom

Echo soundings provided data on the topography of the bottom. Once or twice a day a small dynamite charge was ex-

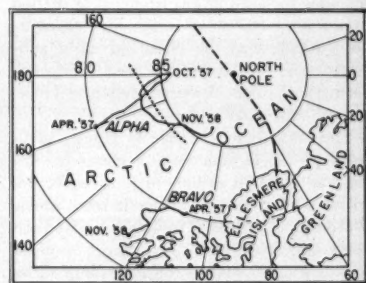


Fig. 1. Movement of US-IGY Drifting Stations Throughout Most of the IGY Period. Dashed line represents approximate crest line of Lomonosov ridge; dotted line represents approximate crest of submarine rise discovered from Drifting Station Alpha.

ploded and the reflections recorded by the seismograph. An array of 12 geophones on the ice served as detectors, allowing the attitude of the reflecting surface to be determined. These spot echo soundings were usually made 1-3 mi apart, depending on the rate of drift. The strike and dip of the bottom, as well as the depth, were measured with each shot. Dips of the ocean floor ranged from 0° to 28° . Although complete analysis of all data has not yet been made, it appears that dips of 2° - 3° are most characteristic in this area. (See Fig. 2.)

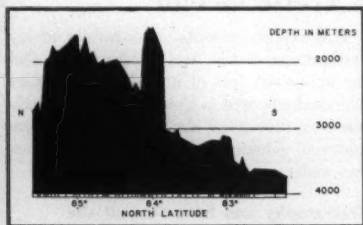


Fig. 2. Profile of Arctic Ocean Floor Approximately Along the 167° W Meridian. Vertical exaggeration is 100:1.

Submarine Ridge: Throughout most of the time the station was occupied, it drifted over a large feature of rough, high topography, which may be classified as a submarine rise (see *Bulletin No. 6*). The wandering path of the floe produced three crossings of this feature (Fig. 1).

The surface of the rise is rugged, with relief of 100 m common; in places the relief was as much as 1000 m. The rise comes within 1400 m of the surface in some areas. Water depths of 3500 to 4000 m exist both north and south of the rise, which appears to be a broader feature than the Lomonosov ridge and apparently runs across the Arctic Basin sub-parallel to it. (The Lomonosov, discovered from Soviet drifting stations in 1948, extends from the New Siberian Islands across the North Pole to Ellesmere Island, dividing the Arctic Basin approxi-

mately in two.) The new rise is higher and more rugged than had at first been realized.

Bottom Materials

Submarine Photography: A Ewing suspended, automatic, submarine camera was used to take pictures of the ocean floor, the first known use of such a camera in the Arctic Ocean. Three camera stations were occupied and about 200 photographs taken in all, each picture covering about one square meter of the bottom. The stations were at $83^{\circ}49'N$, $165^{\circ}05'W$, in 2997 m of water, $83^{\circ}34'N$, $162^{\circ}15'W$, in 2300 m, and $83^{\circ}49'N$, $140^{\circ}04'W$, in 2119 m. A distance of more than 100 mi separates the first and last stations. The photographs revealed smaller features of the Arctic Ocean floor not detected by echo soundings.

An abundance of rocks of all shapes and sizes scattered about the ocean bottom is the most outstanding feature of each of these photographs. The rocks appear to be a general characteristic of the Arctic Ocean floor; such large numbers of them are not seen in bottom photographs taken in temperate latitudes. Although gravel has been dredged from the bottom by workers on IGY Drifting Station Bravo (located several hundred miles south of the last position of Station Alpha), and on Soviet drifting stations, these photographs represent the first observation of the rocks in their original positions, showing their distribution and relative situation in the sediment.

Description of Bottom Gravel: Large numbers of the rocks were brought to the surface in six dredge hauls. They are unsorted (as to size), generally subangular to angular in shape, and of many compositional types. The largest dredged was a 16-lb piece of amphibolite (a crystalline metamorphic rock composed primarily of minerals in the amphibole and plagioclase groups), but the majority of the specimens were limestone. By weight, the limestone fraction of this coarse bottom material was consistently between 50% and 70% (see

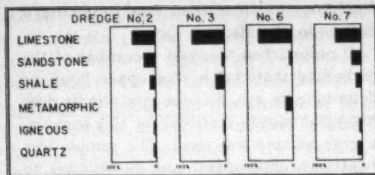


Fig. 3. Distribution of Rock Types in Four Dredge Hauls From Drifting Station Alpha. The material analyzed was of grain size greater than 7 mm. The dredge hauls were made at the following locations: No. 2, 83° 59'N, 161° 44'W; No. 3, 84° 09'N, 160° 23'W; No. 6, 84° 28'N, 148° 28'W; and No. 7, 84° 33'N, 146° 24'W.

Fig. 3). Straie (minute grooves scratched into the surfaces of rocks, usually by debris carried locked in glacial ice) were seen on several of the rocks. These strae, plus the lack of sorting, angularity, and heterogeneous composition of the material, point to ice-rafting as the method of deposition.

Nearly all of the larger rocks have a thin, dark manganese coating on the part that was exposed to the water, the upper part, as they rested on the bottom. Usually, more than half of the rock is covered by manganese, a sharp line separating the coated and uncoated portions showing exactly how the rock rested in the bottom sediment. Empty worm tubes, themselves coated with manganese, were found on the manganese-coated side of many of the rocks. The coating in the tubes suggests that the tubes have been empty for some time. The fact that the worms do not now thrive may be evidence of a change in bottom conditions, possibly a temperature change in the bottom waters.

Fossils of bryozoa (invertebrate colonial animals which secrete calcareous coverings) found in one of the limestone rocks identify the rock as Paleozoic in age (510-180 million years). This suggests a source area in rock layers of the Carboniferous (the coal-forming periods of the Paleozoic Era, ranging from about 255 to 205 million

years ago) of the Canadian Arctic islands, or in the Devonian (315-255 million years ago) of northern Greenland. Further petrographic studies are planned to link the rocks with greater certainty to their source areas. Accurate determination of the on-shore origins of these rocks will furnish clues to the drift of the ice pack in the past.

At the present time, no large detritus, or loose rock debris, is found in sea ice far from land; none was ever seen in the vicinity of Station Alpha. Thus, the pack ice in the vicinity of the station's drift path has probably never been close to shore. Only the ice islands carry large amounts of gravel at present. Hence, the rocks found on the Arctic Ocean bottom have either been dropped by ice islands or were rafted out from shore by sea ice in the past, when the ice may have drifted faster and more freely than at present.

The rocks found on T-3 (Fletcher's Ice Island), the ice island on which station Bravo is situated, are mostly metamorphics—schists and gneisses; hence, it is unlikely that T-3 is the agent which transported and dropped the sedimentary limestones and sandstones dredged from the bottom by personnel on station Alpha.

Marine Life: In several of the bottom photographs, signs of life can be seen. Tall white stalks are probably bryozoan colonies and low, rounded forms appear to be holothurians (free-living animals with elongated, more-or-less cylindrical bodies, also called "sea cucumbers") or gastropods (snails, slugs, etc.). Dredge hauls have brought up both living holothurians and living "brittle stars."

Mounds and holes, some of which may have biological origins, are present in many of the bottom photographs. It seems likely, however, that most of the mounds are buried rocks and most of the holes are impressions left by recently deposited rocks. Generally, signs of life in bottom photographs of the Arctic Ocean are sparser than in similar pictures taken in the Atlantic.

Bottom Sediment Layers: A small piston corer was used to take 15 vertical columns of sediment from the ocean bottom along the station's track. Correlations between the sediment layers are especially good for the upper parts of the cores, which average about 5 ft in length with an overall range of 1-7 ft. Previously, cores were taken in the Arctic Ocean by A. P. Crary (until recently Station Scientific Leader at IGY Little America Station and Deputy Chief Scientist, USNC-IGY Antarctic Program) and by workers on Soviet drifting stations, but the Station Alpha cores are the longest reported and hence go farthest back in geologic time.

Nearly all of the cores contain a characteristic layer, consisting of dark, foraminiferal lutite with some pebbles, extending 10-15 cm down from the top. (Foraminifera are microscopic, hard-shelled animals; lutite refers to rock composed of silt and/or clay and the various associated mud-forming minerals.) Below this layer lies a thicker layer of light-colored lutite, also containing some pebbles but relatively barren of foraminifera. The line between the two layers indicates a change in the

conditions of deposition, most probably a change in climate.

A radiocarbon analysis was made of the carbonate material in the upper layer to determine its age. Since a core sample does not yield enough material for this purpose, a grab sample was used. The sample was relatively undisturbed and is believed to represent nearly the entire thickness of the top layer. The foraminifera, whose presence would have caused errors in the dating, were separated out by sieving. This was possible because the minute animals are nearly uniform in size.

The radiocarbon analysis, performed in the geochemistry laboratory of the Lamont Geological Observatory, yielded an age of 9300 ± 180 years. This age is post-glacial and probably represents an average for all of the post-glacial sediment in the Arctic Ocean, although the sampling method does not allow a positive conclusion. (The Glacial Period, or "Ice Age," is thought by many geologists to have ended about 11,000 years ago.) Some detrital material, in the form of ancient limestone fragments, may have increased the apparent age by a few hundred years.

Wind Transport of Antarctic Snow

This report is based on a paper presented by William W. Vickers, Arctic Institute of North America, at the IGY Symposium during the 125th Meeting of the American Association for the Advancement of Science, Washington, D. C., December 29-30, 1958.

Two major glaciological problems are (1) determining the amount of the world's water locked up in the immense Antarctic icecap, and (2) determining whether this amount is increasing or decreasing. Closely related to the latter are investigations of the transport of snow by wind.

Wind profile studies were made on the Victoria Plateau to ascertain whether the methods of R. A. Bagnold, who correlated

wind speed and the quantity of sand carried by wind, can be adapted to studies of wind transport of snow. This report describes some results of these studies and of observations of the formation and movement of sastrugi (irregular features on the snow surface formed by wind action). The work was done by William W. Vickers under an IGY contract administered by the Arctic Institute of North America.

Wind Transport

Mass-Transport Computation Method: Before investigating desert sands directly, R. A. Bagnold experimented with a laboratory wind tunnel. He was able to determine mathematical relationships between (1) the

wind-velocity gradient perpendicular to the surface, and (2) the quantity of sand carried by the wind past a given point. He expressed this in the form of an equation.

Bagnold pointed up the distinction between laminar and turbulent flow. In laminar flow, the molecules drift steadily, parallel to the surface. When the wind exceeds a critical value, called the Reynolds number (determined by velocity, kinematic viscosity, and, in this case, surface irregularity), turbulence sets in. In turbulent flow, the shearing, or drag, force is transmitted to the surface by the momentum of eddies, rather than by individual molecules. Instead of varying directly with the velocity, the shearing force varies with the square of the velocity. The distribution of velocity with height also differs, no longer varying with height, as in laminar flow, but with the logarithm of the height. The logarithmic profile defines the state of the wind.

Bagnold went on to show that sand movement profoundly alters the state of the wind. The wind strength at which sand of standard diameter, .25 mm, began to move by static fluid pressure alone he called the static threshold. As the load of sand being carried increased, the velocity gradient decreased, owing to the "entanglement" of the grains. This reduced velocity he termed the impact threshold. Once the grains are put into motion, a lower velocity can retain the motion by aid of the saltation principle, which states that once in flight, a grain has a potential energy which is imparted by impact to other loose-lying grains when the first grain lands, supplying the vertical component of movement for the next grain's trajectory; wind friction supplies the horizontal force (see Fig. 4).

The drop in wind momentum from static to impact threshold reflects the energy transferred to the sand grains. A quantitative analysis of this change in velocity gradient enabled Bagnold to calculate the quantity of sand being carried.

Bagnold also arrived at a slightly modi-

fied version of the wind-transport equation based on gradient. The wind velocity, v , at a given height was used instead, as follows:

$$q = \alpha C \sqrt{\frac{d}{D}} \frac{p}{g} (v - V_s)^3$$

where

- α = a constant whose value varies with the surface roughness
- q = quantity of sand in gm/cm width/hr
- C = a constant representing the degree of natural sorting of the grain sizes (equals 1.8 for most dune material)
- d = the average grain size diameter, mm
- D = a standard .25-mm grain size
- ρ = density of the fluid (air)
- g = gravity
- V_s = static threshold in cm/sec

This equation was found best suited for the Antarctic work. (Bagnold notes the minor variation caused by density differences, such as that of snow versus sand. He shows that, compared with the much greater error caused by grain-size variation, the density difference is inconsequential.)

Comparison of Some Antarctic Profiles: Using Bagnold's method of calculation, some Antarctic wind profiles are compared in Table 1. G. H. Liljequist, on the basis of data gathered during the Norwegian-British-Swedish Antarctic Expedition of 1949-52, presented a set of profiles from which a profile can be extracted giving a wind velocity of 950 cm/sec at a one-meter height. This profile was chosen for comparison because it was found to include conditions most similar to the prevailing wind conditions on the Victoria Plateau for which transport figures are computed. A comparable profile by Bagnold is also shown in Table 1. Still another profile is indirectly available from F. Loewe, based on snow transport figures cited in his "Contributions to the Glaciology of the Antarctic," *Journal of Glaciology*, March, 1956.

The equation above has been used for all profiles in Table 1. All factors vary with the individual profile except C , D and g . All velocity measurements are at a height of one meter.

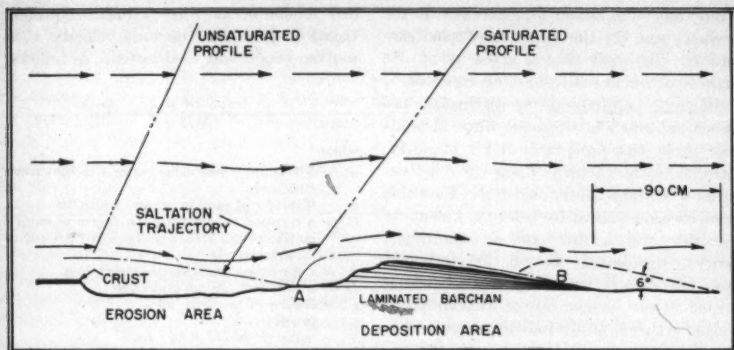


Fig. 4. Diagram of Snow Barchan Showing the Relationship Between the Wind Profile and the Depositional Process. Comparison of the saturated and unsaturated profiles indicates the loss of velocity as the wind takes on a greater load over the erosion area.

TABLE 1

Values of Variables and Computed Quantities of Flow

	Liljequist	Vickers	Bagnold	Loewe
k (cm)	.05	1.5	1.0	.3
d (mm)	.5	.5	.5	.5
ρ (gm/cm ³)	1.37	1.00	1.2	1.37
v (cm/sec)	950	950	950	1750
V_s (cm/sec)	270	340	400	190
q (gm/cm width/sec)	.05	.15	.12*	1.5

* A theoretical snow equivalent for sand.

The Liljequist profile is considered to be the most reliable because of high quality instrumentation and wealth of data.

Vickers' profile differs from that of Liljequist initially in the value of k , in effect, the surface roughness. (k is used in plotting the wind profile, but does not appear directly in the final formula.) This difference is thought to result from the large sastrugi on the Victoria Plateau, where surface irregularities one meter in height are common. The roughness of the Plateau surface alters the drag profile considerably; hence, the large k and V_s . The profile measurements represent an average for the apparent prevailing wind on the Plateau. The calculated snow-transport quantity

shows closer correlation to Bagnold's than to Liljequist's.

Bagnold's profile represents a proven case; a .5 mm-grain size has been substituted for Bagnold's .25 mm for the sake of uniformity, however, and sand density has been converted to that of snow.

Construction of the Loewe profile required many dubious assumptions, which, if correct, result in fairly good correlation for Loewe's case. However, for the same basic figures, Loewe estimates a drift of 29 gm/cm/sec, based on the use of a calibrated snow catcher, in contrast to the figure of 1.5 gm/cm/sec obtained by the formula. It thus appears that there is considerable disparity between the two possible methods, wind profile versus snow catcher, by which one might arrive at working figures for snow transport. Further attention to this problem may result in working figures to satisfy the factor of mass transport by wind in studies of the world's water budget.

Sastrugi Observations

Sastrugi, or skavler (synonymous terms extracted from the Russian and Scandinavian tongues, respectively), means "long-

crested waves." The term is used in Antarctica to include all snow-surface forms resulting from the scouring and filling action of wind. A region of sastrugi somewhat resembles a sand dune desert area, but the features are smaller and take on a greater variety of shapes (see Fig. 5).

The chief importance of sastrugi is its close relationship to the winds. It is anticipated that a knowledge of sastrugi patterns may furnish wind data for unoccupied polar regions. Its alignment, as shown in aerial photos, will give direction. Its manner of deposition and erosion, as well as its general morphology, may assist in the calculation of mass transport of snow by wind.

There are undoubtedly many ways in which a sastrugi surface may be initiated on a flat snow cover. Accordingly, sastrugi deposition as described herein is not necessarily the only way in which the phenomenon may occur.

In the desert, wind at a given height and capable of moving sand will attain a higher velocity over a pebble surface than over a sand surface. The higher velocity is reached because there is little entanglement of air-

borne grains over the pebble surface, since the wind strength is inadequate to start the pebbles saltating. If this same wind were then to encounter a sand surface, its speed would be abruptly checked by loss of energy to the sand load blasted into the air. The wind would drop part of this load a short distance downwind as its velocity fell and carrying power was lost, thus contributing to the growth of a dune as in Fig. 4.

On the icecap, the role of the pebble surface may be taken by any one of many types of surface crusts formed by radiation, condensation, precipitation, or sublimation. Most common, even at very high elevations, is a 2-mm crust of either milky or clear ice. The crusts offer a cemented surface as opposed to a loose-grained surface. The type of surface, of course, determines how saturated a rising wind may become; i.e., how much loose surface material is available for entrainment. The degree of grain saturation of a wind governs its capacity to scour or fill, thus dictating whether the surface forms become erosional or depositional.

The following succession of phenomena

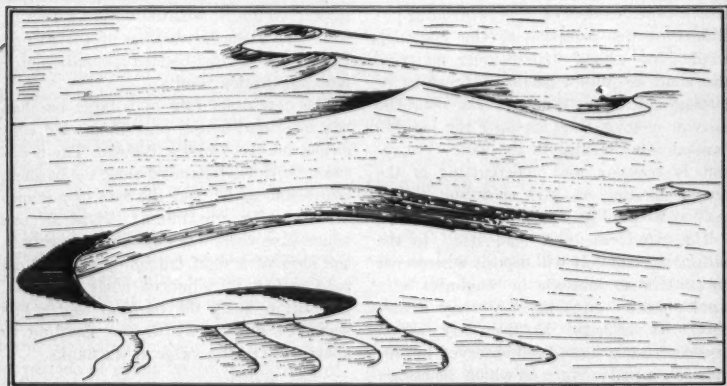


Fig. 5. Example of Sastrugi Surface Near IGY Little America Station. The form in the foreground has been considerably eroded and sculptured by the wind. Based on a US-IGY photograph taken by Herfried Hoinkes.

was observed to produce a loose-grained surface capable of locally retarding a drag profile, thereby causing deposition from the wind-borne load: a light precipitation of stellar and dendritic (branching) snow crystals fell under calm conditions on a smooth, cemented crust 2 mm thick. Then, a light wind rolled these crystals into clusters of about 2-cm diameter by interlocking the spikes of their branches. Further increase of wind speed swept the clusters into groups. The clusters now provided a surface of greater roughness than the smooth crustal surface. With still more wind, such clusters provide a deposition "triggering" surface.

With a large percentage of surface material originally held tightly by crusts, the wind will exceed its threshold velocity before picking up much load and being somewhat reduced in velocity by the added friction. Therefore, the wind reaches a strength capable of moving much more than the normal, loose-lying, 5-mm snow grains. Moreover, these grains, being protected by the crust, cannot be blasted into the air, to check the wind speed by their friction. However, the high velocity wind, unchecked, dislodges much larger pieces of older, broken crusts which came to rest in protruding positions at the cessation of the last high wind. Now armed with heavier material, the wind is quite capable of breaking or pitting the light, 2-mm crusts with the heavier chunks, thus exposing the loosely-bonded 5-mm grains to the wind. The result is scouring and undercutting of the crusts, forming an ever enlarging "blow-out" area (see Fig. 4).

The wind can now load itself to the saturation point. It will deposit wherever it encounters an increase in roughness or a wind shadow—anything that may locally check its velocity. In this way, snow-crystal clusters have been observed to provide the initial surface on which deposition has started. Where small isolated groups of clusters have collected, long, narrow, tapering forms are deposited in their lee, grow-

ing to several times the original cluster height. Adjacent forms often merge, eventually producing a mesa-like structure.

Snow barchans (crescent-shaped dunes), smaller than and lacking the steep "avalanche face" of sand barchans, are quite common. These are deposition forms usually found approximately one saltation trajectory downwind from an active blow-out area. The blow-out area advances downwind with the dune so that deposition-area grains are eventually in the blow-out area, and are, consequently, eroded and transported another trajectory length downwind and again deposited (Fig. 4). The dunes are quite mobile during this cycling.

Slackening of wind will elongate the dune, and a period of immobility will solidify it into a laminated "wind slab." The solidification, as explained by G. Seligman, is brought about by consolidation through the mechanical jiggling caused by saltating-grain impacts on the deposition surface and cementing of grain corners by sublimation. The lamination is due to wind sorting of grains. A very strong wind is needed to erode this now-solid slab, and migration is slow. The dunes take on spectacular contours, with curvature reflecting windward obstacles that set up turbulence. In dunes with cross-bedded lamination, differential erosion results.

The deposition rate of a large barchan was measured during prevailing-wind conditions on the Victoria Plateau. The deposition slope was measured along the barchan center line as 6° , and the rate of advance as 90 cm/hr (maximum). Thus, in one hour's time there was deposition roughly in the form of a right triangle with a 90 cm base and a 6° adjacent angle (Fig. 4). Deposition along the barchan center line was .044 gm/cm width/sec, grading to about 20% of this value at the flanks.

General Conclusions

Qualitative investigation shows the phenomenon of blowing snow in Antarctica to

be remarkably similar to that of blowing sand. Quantitative values primarily based on an established system of investigation are feasible. A correlation of these values

with the wealth of wind data accumulated during the IGY would be of very great value in computing the wind-depletion factor for the Antarctic glacier mass budget.

Some Results of the IGY Island Observatory Program in the Atlantic

This report is based on material supplied by William L. Donn and William T. McGinness of Lamont Geological Observatory, Columbia University.

The IGY Island Observatories in the Atlantic Ocean region, maintained by the Lamont Geological Observatory as part of the IGY Oceanography Program (see *Bulletins* 2, 6, and 9), have yielded a relatively large amount of oceanographic and atmospheric data. Although much of this data will require years for complete analysis, a number of preliminary results of observations of air-ocean coupling, wave types, storm surges and sea-level changes are summarized here.

Ocean waves result primarily from wind action—the “coupling” of the sea surface with atmospheric waves and the transfer of energy from one system to the other. When certain properties of the systems are identical (here, wave velocities and physical dimensions, in particular) the process is termed “resonant coupling.”

Waves seen on the ocean surface are actually the sum of a wide and complex spectrum of wave trains varying in wave length from inches to about a half mile. A wave train travels at a speed proportional to the square root of its wave length; hence, long waves travel fastest and short waves slowest. The first arrivals from a distant storm, then, are relatively long waves having periods of about 20 sec, amplitudes of only a few inches, and wave lengths of several hundred yards; often, these long, low waves can be detected only as “ground

swell” where they are slowed and steepened as they traverse shallow bottoms. This ground swell is followed by a shorter, higher swell carrying most of the wave energy generated by the storm. (The word “swell” usually refers to wind-generated waves that have advanced into a region of calm or of weaker winds.) Finally, there is a shorter, lower swell as the storm effects dissipate. Alternations of high and low wave groups, often observed in the swell from a distant storm, appear to result from wave trains of different wave lengths getting in and out of step. Fluctuation in wave amplitude produced by the mixing of different wave trains is called “beating.”

A wide range of oscillations intermediate in period between the tides and those waves resulting from local wind action and distant storms has also been observed. This group of waves, termed “long-period waves,” includes “surges” and “seiches,” which are discussed elsewhere in this report.

Air-Ocean Coupling of Long-Period Waves

Primarily on the basis of IGY data obtained at Texas Tower No. 4, 85 mi southeast of New York City, it was deduced that 4 to 12-minute dispersive air waves are coupled resonantly to the ocean surface. Pressure oscillations in the atmosphere, recorded on microbarovariographs (*Bulletin* No. 9) at Palisades, New York, and the Texas Tower, appear to travel eastward at about 40 knots along a cold frontal surface extending continuously from the eastern

coast of the United States to a distance beyond Bermuda. (A cold front is the boundary between an advancing cold air mass and a mass of warm air, under which the cold air forces its way, like a wedge.)

Velocities of about 37 knots in the air wave motion were computed from the observed ocean waves; they indicate that resonant transfer of energy is possible over a relatively broad area between the coast and Texas Tower No. 4. Such coupling is necessary to explain long-period ocean waves with heights 70 times greater than those of equilibrium barometric waves (waves whose heights just balance changes in air pressure). Since the internal air waves (those traveling within a medium rather than on its free surface) may be produced by the jet stream or other high winds aloft, the occurrence described above may represent the direct energy coupling between high-altitude winds and the sea surface.

Atmospheric Oscillations

A broad range of atmospheric pressure oscillations, from a few seconds to about 12 hours, has been recorded on microbarovariographs at all of the stations. Oscillations of 1-10 sec are clearly produced by both thermal and wind turbulence. A very striking group of constant-amplitude, constant-frequency oscillations have now been detected at many middle- to high-latitude stations throughout the world. Although these oscillations vary with time and place over the rather small interval of about 20-120 sec, a given series, which may persist for intervals ranging from a few hours to a few days, usually shows a seemingly machine-produced constancy in period and amplitude. Their detection by different types of instruments at widely separated localities in both hemispheres proves their natural origin, however. This effect has been observed only during cold weather, usually with a strong, shallow inversion aloft. Investigation is under way to determine if these constant atmospheric oscilla-

tions represent pressure variations resulting from vertical oscillations in a very stable, low-lying layer.

Another prominent group of atmospheric oscillations, with periods between about 4 and 20 min, appears to be best explained at present as surface pressure perturbations produced through the passage of internal waves along a frontal surface aloft. These oscillations often show the strong dispersion effects characteristic of wave-group propagation in a dispersive medium.

Oscillations with a semidiurnal period are usually detectable when the instruments are adjusted with appropriate time constants. These phenomena, gross compared with the micro-oscillations described above, are probably tidal (solar or lunar) in origin. For the most part, these oscillations go undetected by conventional microbarographs, or, if detected, are not resolved in adequate detail for useful analysis.

Long-Period Coastal Waves

Long-period waves seem to characterize many coastal areas, including those of relatively small islands. On the exposed southeast coast of Bermuda, these waves show characteristic oscillations of 6 to 8 min. On the southern coast of Terceira (Azores) they frequently show 8- to 10-min oscillations, while on the southern coast of Iceland, quite regular 16-min oscillations were observed during quiet-sea conditions.

These waves, which may reach amplitudes of about two centimeters, are often remarkably uniform (sinusoidal) in shape; in addition, they seem to have a spectrum unique to a particular area. These waves have been recorded on underwater pressure heads, instruments sensitive to changes in pressure produced by wave motion and usually installed at a depth of 30 ft. Most of the instruments are located off open coasts or coasts having a broad concave curvature; hence, the oscillations are not likely to be a function of harbor resonance.

During local storms, a complex spectrum

of long-period oscillations with periods ranging between about 1 and 25 min was found to exist in coastal regions. Such oscillations have not yet been detected at Texas Tower No. 4, which stands in about 30 fathoms of open water. This, together with the characteristic period relationships, suggests that the oscillations are a coastal resonance phenomenon rather than a simple coastal amplification of long waves traveling in from the ocean.

Coastal and Deep-Water Waves

Comparison of both short- and long-period wave recordings from the Texas Tower with those from coastal installations, both island and continental, shows a rather striking contrast. All wave records made in the relatively open ocean area in which the tower stands appear in striking sinusoidal groups, suggesting a relatively narrow power range. Short-period (gravity) waves recorded in deep water occur in very uniform, undistorted groups, closely resembling classical beat patterns. Waves recorded in shallow water off coasts show far more irregular patterns, indicating a greater spread of frequencies, more complex interference from coastal reflections, or a combination of both.

Long waves recorded in deep water also appear smoother than those offshore. As noted above, the characteristic low-frequency waves have not been recorded, and it appears thus far that most such waves in deep water are related to similar oscillations in the atmosphere. Another very striking difference between coastal and deep water long-wave records is the strong "surf beat" indicated by the former, particularly at times of strong short-wave activity, and the complete absence of surf beat in the deep-water records. (Surf beat refers to irregular oscillations of the near-shore water level at intervals of several minutes.) These observations support the explanation of surf beat as a coastal effect resulting from the mass transport of water through

wave-group activity. A maximum amplitude of several inches was observed when such activity was high.

Storm Surges in the Lesser Antilles

Islands of the Lesser Antilles, particularly Barbados, the easternmost, have long been beset by severe and damaging sea surges. (Surges have periods generally between about 30 sec and 1 hr and are usually less than .3 ft high.) These sea surges, which may continue for a day or more, arise with little warning and are unrelated to local weather. Attempts to explain them in terms of submarine landslides or earthquakes have proved unsuccessful. Four occurrences of sea surges have now been explained, however, by means of IGY data.

Intense North Atlantic storms having the appropriate fetch (distance the wind blows over the water in a particular direction) can generate long-period ocean swell (15-20 sec) spreading toward the Lesser Antilles. If the swell maximum arrives at low tide, much of its energy is expended on the outer reefs. If it arrives at high tide—particularly spring high tide—the long-period swell crosses the reef and develops high and damaging surf at the shore. If the swell maximum is protracted, surf conditions vary with the tide until the swell subsides.

From these studies, it now seems possible to forecast sea surges two or more days ahead through storm locations shown on synoptic charts and allowance of appropriate travel time for the swell generated.

Seiche Observations

Because the tide gauges were installed on long piers usually located in sheltered water bodies, seiche oscillations of these water bodies have been well recorded. (A seiche is an oscillation whose period, generally from a few minutes to an hour or more, is determined by the basin's physical dimensions.) Most seiches are of meteorologic origin, but possible coupling to seismic surface waves is being investigated. Simple

periodicities were recorded only by instruments located in uniformly enclosed harbor or bay regions. Elsewhere, the seiche spectrum may be continuous, as at Grindavik, Iceland, or discontinuous, as in St. George's Harbor, Bermuda.

Grindavik exhibits a 12-ft tide range; superimposed on the tide wave is a seiche with a period spectrum of 4-10 min, varying directly with sea-level height. At high tide, the size of the oscillating area increases from flooding and the average depth of the oscillating basin decreases, giving the observed effect. At Bermuda, seiche oscillations show fairly discrete periods of 10 and 40 min. The shorter period is associated

with the smaller water body at St. George's Harbor, and the longer with the much larger water body shoreward from the outer reef of the Bermuda platform.

Sea-Level Changes

Certain sea-level phenomena must be related to temporary current changes and probably reflect a local variation in the vertical ocean structure. An example of local variation is the anomalous drop in sea level of 0.75 ft recorded in August 1958 at Bermuda (supported by independent observations of the US Coast and Geodetic Survey). In September, sea level returned to its July value.

Fifth US-IGY Earth Satellite

The fifth US-IGY satellite, 1959 Alpha (Vanguard II), was launched from Cape Canaveral, Florida, at 10:55 am EST on February 17, 1959. It was injected into orbit 10 min later. The launching vehicle, the three-stage, 72-ft, 22,600-lb Vanguard rocket developed by the US Naval Research Laboratory, was essentially the same as that used to put 1958 Beta (the Vanguard I test sphere) into orbit (see *Bulletin No. 11*).

The cloud-cover satellite, a project of the National Aeronautics and Space Administration (NASA), was instrumented to measure cloud-cover distribution over the daylight portion of its orbit. These data will be related to the over-all meteorology of the earth.

Satellite Characteristics: 1959 Alpha is a sphere 20 inches in diameter and weighing 21.5 lbs. The outside is plated with pure gold polished to a mirror-bright finish. This highly reflective surface was designed to balance radiation from the satellite against the heat from the sun and from the satellite's batteries, providing a sufficiently cool

environment for proper functioning of the instrumentation. The 5.5×12 -in, cylindrical instrument package is supported by an internal framework of magnesium tubing. (See Fig. 6).

Cloud-Cover Experiment and Instrumentation: The cloud-cover experiment developed by the US Army Signal Research and Development Laboratory at Fort Monmouth, N. J., utilized two photocells, each at the focus of one of two optical telescopes aimed in diametrically opposite directions at an angle of 45° from the spin axis of the satellite. As the satellite circled the earth, the photocells measured the varying intensities of sunlight reflected from clouds (about 80%), land masses (15-20%), and sea areas (5%). The satellite's spin, about 50 rpm, caused the photocells to scan the earth in successive lines, producing a lined picture not unlike a television picture.

The measured reflection intensities were converted into electrical signals, which were stored in a tape recorder within the instrument package. Separate solar batteries turned on the recorder only when the

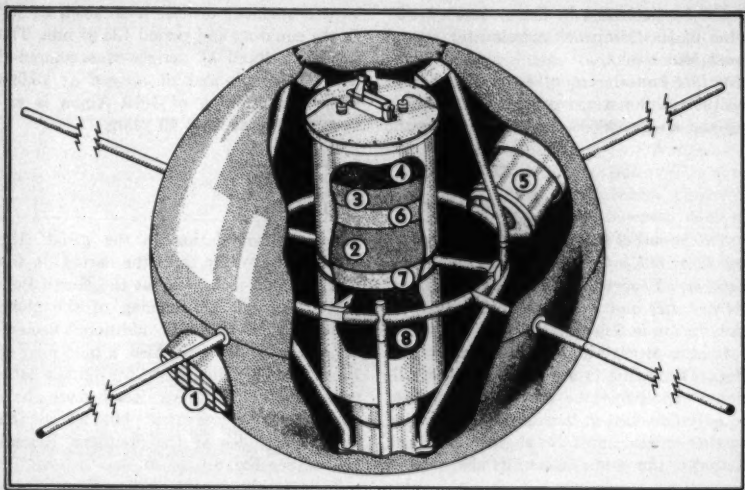


Fig. 6. Cutaway Diagram of Satellite 1969 Alpha. The instrumentation consists of (1) photocell light shields, (2) recorder, (3) interrogation radio receiver, (4) meteorological data transmitter, (5) photocell, (6) data electronic equipment, (7) tracking transmitter, and (8) mercury-cell batteries. From US Army photograph.

earth beneath the satellite was in daylight, giving 50 min of data per orbit. The 75-ft loop of recording tape accommodated all scanning data from the sunlit part of a single orbit. Once in each orbit, a selected ground station interrogated the satellite by signalling a command receiver within the satellite, causing the entire tape to be played back in 60 sec. The tape was then "erased" and the system triggered to begin recording again. At the interrogating ground station, the data were received on a wide-band magnetic tape recorder and the tape was immediately air-mailed to the US Army Signal Research and Development Laboratory for analysis and conversion into cloud-cover pictures.

The experiment was designed to obtain cloud-cover data between the equator and 35° to 40° north latitude. (Although the satellite's orbit covered an equivalent area south of the equator, most of this region

was in darkness during the times the satellite passed over it.) According to the original plan, cloud-cover data was to be obtained for 600-mile-wide strips on each pass, totaling about 25% of the earth's sunlit surface in a 24-hour period. The exact coverage, however, depends upon the many orbital variables.

Radio Equipment: The radio transmitter for the cloud-cover experiment used a frequency of 108.03 megacycles at a power level of one watt, modulated by signals from 2500 to 12,500 cycles/sec. The expected lifetime of the batteries for both the experiment and its radio transmitter was at least two weeks. The Minitrack transmitter sent a continuous, unmodulated signal at 108.00 mc with a power level of 10 milliwatts. This transmitter carried a temperature-sensitive quartz crystal which varied the frequency such that the internal temperature of the instrument package

could be determined. The estimated lifetime of the Minitrack transmitter was at least four weeks.

Orbit: Initial computations of the orbit of 1959 Alpha were: perigee 346.9 statute mi and apogee 2065.1 statute mi above the

earth's surface; orbital inclination 32.86° to the equator; and period 125.85 min. The satellite's speed at perigee was computed as 18,312 mph and at apogee as 13,093 mph. The lifetime of 1959 Alpha is expected to be at least 10 years.

Earth's Shape

This report is based on material prepared by J. A. O'Keefe, Ann Eckels, and R. K. Squires, Theoretical Division, National Aeronautics and Space Administration, for publication in Science.

Studies of variations in the orbit of 1958 Beta (Vanguard I) suggest that the traditional concept of the earth as a spheroid equally flattened at both poles and bulging at the equator must be slightly modified. Actually, the studies show, its shape has a component somewhat resembling a pear (see Fig. 7).

Certain variations in satellite orbits are attributable to regional differences in the earth's mass, or, more specifically, differences in the gravitational force acting on the satellite. Since such orbital variations are periodic, the gravitational variations which cause them can be analyzed in terms of harmonic components. There are many types of harmonics, which, when plotted graphically, appear as waves; those which vary with latitude only are termed "zonal harmonics."

Calculations show that periodic variations in the orbit of 1958 Beta can be explained by a third zonal harmonic in the earth's gravitational field. The third zonal harmonic appears as three waves, each equal to one-third the circumference of the earth. The amplitude of this third zonal harmonic—that is, the extent to which its maximum gravity values vary from the average—is 4.7 milligals. (A milligal, or mgal, is one-thousandth of a gal, which is an acceleration due to gravity of one cm/sec².) This gravity variation implies 15

meters of undulation in the geoid (the mean-sea-level figure of the earth), in the form of a 15-meter rise at the North Pole from the general flattening of the globe there, and 15-meters of additional flattening at the South Pole. Also, a flattening of 7.5 meters is indicated in the middle latitudes of the Northern Hemisphere, balanced by an equivalent bulging in the middle latitudes of the Southern Hemisphere. (See Fig. 8.)

Thus, establishment of the existence of a third zonal harmonic requires slight modification of the geoid toward the shape of a pear, with the stem end up, i.e., at the North Pole.

In principle, the perturbation of the 1958 Beta orbit might be caused by harmonics with either an odd or an even number of waves. The even harmonics can be excluded as a cause, however, because they would show similar effects in both hemispheres, whereas the actual observed effects are opposite in the Northern and Southern Hemisphere. Harmonics which depend on longitude as well as latitude (known as tesseral harmonics) can also be excluded, because these too are the same in both hemispheres, apart from a shift with longitude. This leaves only the zonal harmonics of odd degree as possible explanations of the variations in the orbit of 1958 Beta.

Of these odd harmonics, the first degree is nearly zero because the center of the system on which the computations are based—the Vanguard coordinate system, set up by the Army Map Service—coincides with the earth's center, to an accuracy of about

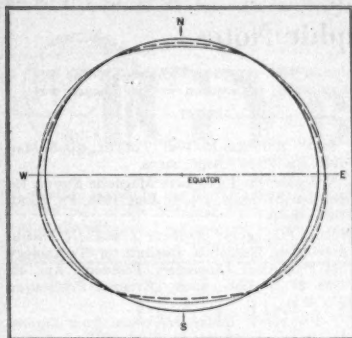


Fig. 7. Concepts of the Earth's Shape. Solid line represents a perfect sphere; dotted line indicates the traditional view of flattening at the poles and bulging at the equator; dashed line depicts slightly pear-shaped earth suggested by perturbations in the Vanguard I orbit. Both dotted and dashed lines greatly exaggerate the actual deviations from a perfect sphere. The exaggeration of the dashed lines is especially great in order to emphasize the new findings; actual distances at the poles from the solid to the dotted line are about 1000 times as great as from the dotted to the dashed line.

100 m. Accordingly, the first zonal harmonic is much too small to produce the observed effect. Odd harmonics of high degree are unlikely to have a large effect because they die out inversely as the $(n + 1)$ power of the distance from the earth's center, where n is the degree of the harmonic.

By a process of elimination, therefore, it was concluded that the perturbation in the satellite orbit is due mostly to the third zonal harmonic, with a possible contribution from the fifth.

By applying to the variations observed in the orbital elements of 1958 Beta certain relations derived by H. Jeffreys, the value of 4.7 ± 0.4 mgal for the third zonal harmonic of gravity at the earth's surface is obtained. This finding contrasts with the "basic hypothesis of geodesy" of F. A.

Vening Meinesz and W. A. Heiskanen. They assume that the earth's gravitational field closely approximates that of a fluid in equilibrium and that deviations from such an ellipsoid in any given area do not exceed 30 mgals over an area of 1000 km on a side, i.e., 30 mgal(megameter)², or 3 mgals as gravity variations average out over an area 3000 km on a side. In the NASA Theoretical Division calculations, however, each of the polar areas has a deviation of about 120 mgal(megameter)² and each of the equatorial belts a deviation more than twice as great.

The presence of a third zonal harmonic of this large amplitude indicates a very substantial force acting on the surface of the earth. Following the methods of Jeffreys, this crustal load is calculated to be 2×10^7 dynes/cm². Hence, either stresses of approximately this order of magnitude exist down to the core of the earth, or stresses about four times as great exist in the uppermost 700 km only. These stresses must be supported either by a mechanical strength greater than usually assumed for the interior of the earth, or by large-scale convection currents in the earth's mantle.

The orbital data for Vanguard I was furnished by the Vanguard Minitrack Branch, under the direction of John T. Mengel; by the IBM Vanguard Computing Center, under the direction of Joseph W. Siry; and by Paul Herget, then consultant for the Naval Research Laboratory.

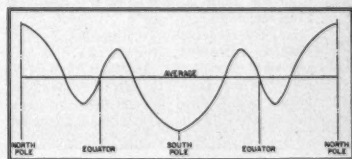


Fig. 8. Symbolic Representation of the Third Zonal Harmonic of the Earth's Gravitational Field. (Not drawn to scale.)

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Data Center Reports

Rocket and Satellite Report Series: The following numbers of the IGY World Data Center A Rocket and Satellite Report Series have been issued since the last announcement (see *Bulletin* 19). They are available from the National Academy of Sciences at \$1.00 each:

Satellite Report No. 7—Simplified Satellite Prediction from Modified Orbital Elements.

Rocket Report No. 2—Flight Summaries for US Rocketry Program for the IGY, Part I: 5 July 1956-30 June 1958 (in preparation—Part II: 1 July 1958-31 December 1958).

Glaciological Report Series: Not available from the National Academy of Sciences. May be obtained at \$3.00 per copy from:

IGY World Data Center A: Glaciology
American Geographical Society
Broadway at 156th Street
New York 32, New York

No. 1—Preliminary Reports of the Antarctic and Northern Hemisphere Glaciology Programs (July 1958). Second edition, without illustrations.

No. 2—Further Reports on the IGY glaciology program in Antarctica (in preparation—title tentative).

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Lyman-Alpha Photographs of the Sun's Disk

The following report is based on material supplied by J. Dewitt Purcell and Richard Tousey, of the Naval Research Laboratory.

The sun is commonly thought of as a smooth yellowish disk occasionally marred by small dark blemishes called sunspots. Actually, the sun has as many different faces as astronomers can find wave lengths of radiation in which to observe it. In the red light of excited hydrogen, it shows fuzzy, lacy bright areas (plages) and a turbulent, grainy surface. In calcium violet light it takes on a mottled surface appearance that has been likened to the skin of an orange, with the plage regions showing even brighter. Recently, for the first time, highly detailed photographs of the entire sun were taken in the light of the Lyman-alpha line of hydrogen. (An earlier photograph, obtained by W. A. Rense from a rocket flown in 1956, suggested strongly that Lyman-alpha radiation was not emitted uniformly by the surface of the sun. However, the image was faint and lacked sufficient resolution to outline the edge of the solar disk or to make possible a detailed correlation with photographs at other wave lengths.)

Lyman-alpha light is in the extreme ultraviolet region of the spectrum, midway between visible light and X-rays. It originates in regions of the solar atmosphere

4000-6000 mi above the sun's surface. When large amounts are absorbed by the D-region of the earth's ionosphere, this radiation may have a powerful effect on radio communications, causing disruption or changing the quality of transmission on many short-wave radio wave lengths.

The photographs were taken from an altitude of 123 mi by a small, specially-constructed solar observatory in the nose



Fig. 1. Rocket Photograph of Sun in Light of Lyman-alpha Radiation. Bright areas are high-temperature, Lyman-alpha-emitting gas clouds high in the solar atmosphere. Darker areas are cooler and at lower levels. Official US Navy photograph.

of an Aerobee-Hi rocket launched from White Sands, New Mexico, on March 13, 1959. The experiment was designed and the launching conducted by the Naval Research Laboratory as part of the IGY Solar Activity Program.

The Experiment

Although the sun has in the past been photographed frequently in light of various other wave lengths, highly detailed photographs have never before been obtained in the light of Lyman-alpha, most of which is absorbed in the D-region, 40-55 mi above the earth's surface. The photographs, 60 of which were obtained within a period of about a minute, show great, bright, irregular clouds of hydrogen gas high in the solar atmosphere. The clouds cover about $\frac{1}{2}$ of the disk, mostly in the sun's northern hemisphere, and have temperatures in excess of 6000°C. (See Fig. 1.)

During the rocket flight on which these Lyman-alpha photographs of the sun were made, hydrogen red line, and calcium K line photographs were also being made from the ground at the Mount Wilson Observatory in California, the McMath-Hulbert Observatory in Michigan, the Air Force Observatory at Sacramento Peak in New Mexico, and at NRL in Washington. Comparison of the solar phenomena mapped at these three widely-separated wave lengths is expected to throw new light on the process by which solar energy released inside the sun by nuclear reactions reaches the surface and escapes.

The new Lyman-alpha photographs show the solar weather pattern at the highest level in the solar atmosphere as yet studied over the entire surface of the sun. Calcium K line photographs map the sun's atmosphere farther down into the interior (from the surface to a height of 4000 mi), and photographs in the red line of hydrogen show the pattern still lower in the atmosphere (surface to 200 mi). Thus, photographs at these three levels, when analyzed together, give a sort of three-dimensional

picture of the processes taking place in the sun's atmosphere.

It is apparent that the sun is strikingly stormy when viewed by the extreme ultraviolet light of hydrogen. The same bright disturbed areas are present also in the photographs taken from the earth's surface, but they are smaller and not as conspicuous. The pattern appears to become coarser at higher levels. Though in part, perhaps, ascribable to instrument effects, this agrees with the concept of ascending columns of turbulent gas, spreading, combining, and merging as they stream out of the sun. Eventually, traces of these gases reach the earth. Occasionally, during periods of great solar activity, they produce auroras and magnetic storms and disrupt radio communications.

Instrumentation

The spectrographic camera with which these extreme ultraviolet photographs were obtained was the result of four years of development at the Naval Research Laboratory. Since Lyman-alpha radiation is strongly absorbed by all materials, lenses could not be used and it was necessary to construct the entire camera with mirrors. These were not ordinary mirrors, however, but diffraction gratings, mirror surfaces ruled with 15,000 lines to the inch. These rulings cause the intense visible light from the sun to be thrown out of the camera, leaving only the monochromatic Lyman-alpha radiation to form the solar image.

Ordinary film cannot be used to photograph this image because the gelatine binder in the emulsion absorbs the extreme ultraviolet radiation before it can reach the sensitive silver-halide grains. A special film containing almost no gelatine must be used. This film is very fragile and care must be taken not to touch the surface or the image will be wiped off.

Once the equipment is in flight, it is still a difficult problem to ensure taking good pictures because the rocket's flight path is certain to be unstable—rolling, pitching, and

yawing. Precise pointing is essential, as it is to any astronomical telescope. To keep the entire instrument pointed at the sun, a complicated servo system, constructed by physicists at the University of Colorado, was employed. This control system scrutinizes the sun with photoelectric eyes, which feed back into the servo-motors signals telling them which way to correct the pointing of the camera.

The spectrograph used weighed about 35 lbs and the entire payload about 250 lbs.

Conclusions

With these refined techniques, evidences of weather in different parts of the solar atmosphere may be seen and attempts made to correlate the more violent changes in solar weather with terrestrial ionospheric weather and, possibly, with local weather. It is known that solar changes observed with visible light are only indirect indicators

of what is happening in the more energetic, invisible ultraviolet and X-ray emissions. Photography of the sun in wave lengths of these powerful short-wave radiations makes possible a tremendous advance toward understanding the relationship between solar activity and its terrestrial consequences.

Lyman-alpha pictures such as those obtained on the March 13 rocket flight show that the radiation is emitted from spots and patches over the solar surface. This knowledge may help us to understand the reasons for the wide range of variations and the rapid changes in quality of radio propagation.

Eventually, such rocket astronomy techniques, leading to the discovery of phenomena forbidden to earth-bound astronomers, may permit routine photography of the sun in the most important short-wave radiations, providing daily solar weather reports for predictions of terrestrial responses.

Studies of Solar Flares and Flare-Associated Terrestrial Phenomena

The following report was prepared by Mary L. Andrews of the High Altitude Observatory, University of Colorado, Boulder, Colorado.

The IGY Solar Activity Program at participating solar observatories in the United States has included studies in basic solar physics and a warning service for upper-atmosphere scientists. The solar physics studies are concerned with physical and chemical properties, processes, and structure of the sun. The warning service (see World

Days Report, this issue) is designed to give advance notice for observation of possible magnetic and ionospheric disturbances, and other solar-terrestrial effects, when solar outbreaks have been observed.

One of the major research interests of the High Altitude Observatory of the University of Colorado during the IGY has been the study of solar and terrestrial phenomena associated with flares. Such studies aim toward a better understanding of solar flares themselves as well as of their effects on the ionosphere—the electrically-charged, or ion-

ized, region of the earth's atmosphere. Although flares apparently are the most important of solar events affecting the earth, they are probably the least understood. There is no generally accepted theory of their origin, of the source of the energy they release, or of the precise nature of the emissions from them that so profoundly influence the earth's outer atmosphere.

The Physics of Flares and Related Phenomena

Flares are usually observable only in certain light wave lengths originating in the chromosphere (the lowest level of the solar atmosphere), such as the light of ionized hydrogen and calcium. To an observer viewing the sun through a filter that restricts the light to one of these wave lengths, the flare appears as a sudden brightening of a spot on the disk or limb (outer edge). The typical flare brightens to its maximum intensity in a few minutes then fades gradually in about an hour.

Most flares appear in the bright plage, or disturbed, area surrounding a sunspot group. When seen on the limb, filamented coronal structure is usually seen to be associated with such active regions, often at temperatures considerably hotter than the surrounding coronal gas. (The corona is above the chromosphere in the sun's atmosphere.) Out of these active regions, loop-like prominences, or solar gas clouds, condense. In fact, the tightly-curved loop prominences seen associated with flares sometimes appear to be the flares themselves.

H. Zirin and E. Tandberg-Hanssen of HAO undertook detailed study of the different physical conditions in two types of flare-connected phenomena—loop prominences and surges. (Surges, highly-luminous jets of solar gas rising to heights of 100,000 km or more, may or may not accompany flares; the largest, however, are associated with flares. Surges last about 20 min.) To avoid the difficulties of interpreting the spectra of flares and prominences seen

against the background radiation of the disk, the investigators worked with spectra of these phenomena photographed above the limb.

Two bright, flare-like loop prominences appeared on the limb on November 12 and 22, 1956. G. W. Curtis and K. Watson obtained spectra showing hydrogen, neutral helium, and ionized helium lines. From an analysis of these observations, Zirin and Tandberg-Hanssen concluded that the loop prominences have different temperature regions, with ionized helium lines coming from a much hotter region (approximately 100,000°K) than either the neutral helium or hydrogen emissions.¹

On December 18, 1956, Watson procured spectra of an intense limb flare condensing out of the corona in the form of a loop prominence. There was strong continuous emission from the flare, due to electron scattering, and strong coronal emissions in the yellow line at 5694 Å and the blue line at 4086 Å, from CaXIII. From the behavior of the two coronal lines, Zirin confirmed earlier identification of the yellow line as emission from CaXV.²

On December 19, 1956, a bright loop prominence and intense surges appeared at different places on the limb. Watson's spectra, showing both hydrogen and helium as well as the spectrum lines of metals, enabled Tandberg-Hanssen to extend the previous study of temperature variations within loop prominences and to compare these with temperatures in the surges.

The metal lines in both types of phenomena apparently came from regions different from those responsible for the helium and hydrogen lines. The loop prominence was intimately connected with the corona, while the surges welled up from below. The line profiles for the loop broad-

¹ H. Zirin and E. Tandberg-Hanssen, "Physical Conditions in Limb Flares and Active Prominences I. The Loop Prominences of 12 Nov. and 22 Nov. 1956." *Astrophysical Journal*, March 1959.

² H. Zirin, "Physical Conditions in Limb Flares and Active Prominences II. A Remarkable Limb Flare, 18 Dec. 1956." *Astrophysical Journal*, March 1959.

ened toward the top, indicating increasing temperatures away from the limb. Line profiles for the surges, on the other hand, suggested decreasing temperatures as the material shot farther outward from the solar surface.³

Solar-Terrestrial Effects

Although ionospheric disturbances, geomagnetic variations, and auroras frequently follow flares, only a few of the solar emissions, both radiational and corpuscular, which enter the earth's atmosphere have as yet been identified. Similarly, the physical mechanisms in the earth's atmosphere that produce these terrestrial effects still present many unsolved problems.

Radio-wave Absorption: J. W. Warwick and H. Zirin are attempting to determine the nature of the flare radiation that causes sudden ionospheric disturbances. As a first step, they studied records of flare-induced ionospheric radio-wave absorption obtained with the IGY SCNA (sudden cosmic-noise absorption) recorder in Boulder.

Assuming that the ionizing flare radiation was Lyman alpha and making certain other assumptions about the response of the atmosphere to this ionizing radiation, Warwick and Zirin analyzed the absorption data for the earth's atmosphere associated with five flares. (A recent rocket finding suggested that ionizing radiation occurring during a flare was X-rays [*Bulletin No. 19*]. Warwick and Zirin note, however, that the beginning of a flare may be missed in a rocket experiment as the rocket is not usually launched until after the flare has begun. They suggest that the sudden cosmic noise absorption accompanying a flare may result from a Lyman-alpha burst at the very start of the flare.) In the analysis, they found it necessary to use a very large value for the effective recombination coefficient to fit the observed absorption as a function of time

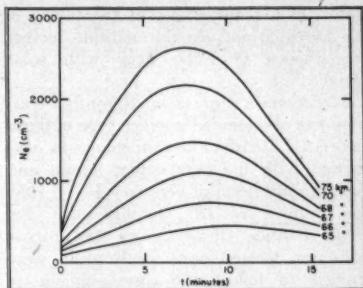


Fig. 2. Electron Densities at Particular Heights, as a Function of Time, from the SCNA Record of February 8, 1957:1733 UT. A recombination coefficient of 5×10^{-8} is indicated. The plot shows the lag in response by the lowest ionospheric levels following an impulse of radiation at some earlier time. The symbol N_e represents the electron density.

throughout the flare; the best fit was obtained by a coefficient of 5×10^{-8} cm^3/sec . With this value they calculated electron densities as a function of time and height (see Fig. 2).

(The great increase of ultraviolet radiation resulting from a flare causes a corresponding increase of ionization in the D-region, the lowest region of the ionosphere, owing to loss of electrons by upper-air molecules. As the flare diminishes in intensity, recombination of the free electrons with ionized air molecules takes place. The effective recombination coefficient describes the rate at which free electrons are removed from the atmosphere in this way, and through certain other processes.)

Although this analysis was predicated on a simple theory of formation of the D-region, the results would probably hold also for more complex theories, at least for those in which the ionizing flux varies uniformly at all wave lengths as a function of time. The principal conclusion was that the D-region remains essentially in radiative equilibrium, with the rate of ionization balancing the rate of recombination. This conclusion

³ E. Tandberg-Hanssen, "Physical Conditions in Limb Flares and Active Prominences of 19 Dec. 1956," (to be published in *Astrophysical Journal*, July 1959).

results in a simplification of the theory of the D-region and should facilitate further comparisons of radio data with solar activity.⁴

Cosmic-noise Absorption: Recently, Warwick has also studied another type of flare-associated atmospheric disturbance in connection with the outstanding aurora and geomagnetic storm of February 10-11, 1958 (see *Bulletin No. 18*). On that night, the High Altitude Observatory's two corner reflectors, located north of Boulder, were trained to follow the cosmic-radio-noise source Cygnus A as it circled across the low northern sky. Rigged as an interferometer, the reflectors record cosmic-noise absorption at 18 mc.

From antenna records of signal strength during the night of February 10-11, Warwick found an area of 100% absorption to the northeast and about 10° above the horizon. This area corresponded with the region in which the auroral arc would presumably have been visible had the night

been clear in Boulder. This was also the area for which S. Matsushita postulated intense electric currents (discussed below), and in which J. R. Winckler and others observed X-radiation.

The detailed time variations of the absorbing region found by Warwick followed closely the time variations of absorption over the entire sky as measured by the Boulder SCNA recorder. These observations indicate that the ionizing particles ultimately responsible for the absorbing region during the February 10-11 event simultaneously affected an enormous region of North America.⁵

Magnetic Variations: S. Matsushita studied records of magnetic variations for the February 10-11 disturbance from a network of seven closely-spaced stations in the central United States and from the observing stations at Fredericksburg, Va., and Tucson, Ariz. This close network was established for the IGY by the Coast and Geodetic Survey (see *Bulletins 3* and *18*).

Matsushita found that during magnetic

⁴ J. W. Warwick and H. Zirin, Scientific Report No. 9, ARDC Contract AF19(604) 1491, January 1958.

⁵ J. Warwick, *Science* 127, 1047, 1958

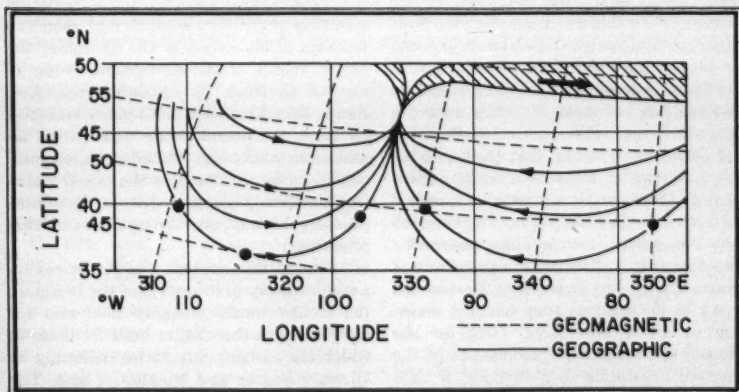


Fig. 3. Current Pattern Suggested by Geomagnetic and Ionospheric Observations During the February 10-11, 1958 Magnetic Storm. The hatched area at the top represents the strong auroral current at 100 km. The five stations shown by the large black dots are, from west to east: Price, Utah; Espanola, New Mexico; Beloit, Kansas; Carrollton, Missouri; and Fredericksburg, Virginia.

disturbances the variations of the earth's magnetic field at the seven stations are usually quite similar, although on some occasions there have been significant differences. For the February 10-11 storm, the stations at Carrollton, Mo., and Fredericksburg recorded negative bay-shaped variations in the horizontal component of the field, while the western stations showed positive variations in the same component. At the intermediate station in Beloit, Kan., the horizontal variation was first negative and then positive.

Ionograms, photographic records relating the heights of radio-signal echoes to the different radio frequencies, were obtained with vertical incidence ionosondes at Washington, D. C. (Ft. Belvoir, Va.), Boulder,

Colo., White Sands, N. M., and San Francisco, Calif., during the February 10-11 storm. The records showed that the area of strong radio absorption expanded toward lower geomagnetic latitudes.

Matsushita therefore suggests that on this occasion the strong electric current flowing in the auroral zone at a height of about 100 km moved to a much lower magnetic latitude than usual. Leaks from this current at low latitudes could have created a current pattern similar to that shown in Figure 3, which fits the observed variations at the different stations.*

* S. Matsushita, High Altitude Observatory Solar Research Memorandum, No. 119, November 1958.

Antarctic Snow Stratigraphy

This report is based on part of a paper presented by William W. Vickers, Arctic Institute of North America, at the IGY Symposium during the 125th Meeting of the American Association for the Advancement of Science, Washington, D. C., December 29-30, 1958.

In an effort to determine the pattern and rate of snow accumulation in the Antarctic, layering visible in the walls of pits dug in the snow at several IGY scientific stations was studied.

This report describes some results of studies performed by William W. Vickers under an IGY contract administered by the Arctic Institute of North America. (Related investigations of wind transport of snow were reported in *Bulletin No. 22*.)

Accumulation and Snow Stratigraphy

For determinations of the volume of Antarctic ice, seismic methods are employed

to obtain the important depth dimension. To determine the change in volume, however, several simultaneous processes must be examined—mass dissipation by heat, calving of icebergs along the coast, wind transport of snow, and the annual snow accumulation. Studies of snow stratigraphy, or layering, are an important part of the snow accumulation investigations.

Layering exists in the walls of snow pits much as earth strata in a large road-cut. Summer and winter snow layers show different characteristics, which, when closely examined, enable the years to be distinguished. This type of investigation was first carried out successfully in Greenland. However, there was some doubt that the method could be readily applied in Antarctica where very low temperatures over most of the continent throughout the year do not allow easily identified summer-melt characteristics to form.

In order to verify the method for Ant-

arectica, a 23-ft pit was excavated at the site of Admiral Byrd's 1939 camp, Little America III. Byrd's "snow cruiser," a bus-like vehicle intended for use on this earlier expedition, was found resting on the 1939-40 summer snow layer, and could, therefore, serve as a bench mark for stratigraphic studies down to this level. The snow-stratigraphy interpretations made in this pit were found to be in error by one year for this interval of 18 years. (See Fig. 4.)

The stratigraphy recorded in Antarctic snow pits is now being analyzed at the Ohio State University Glaciological Data Reduction Center, under the direction of Richard P. Goldthwait. Annual accumulation for areas thus far reported is as follows:

Station	Accumulation (cm)	Source
Byrd	14	V. H. Anderson
Ellsworth	20	P. T. Walker
Little America III	16.2	W. W. Vickers
Little America V	15.5	W. W. Vickers
Victoria Plateau	16.3	W. W. Vickers
Wilkes	14	R. L. Cameron

The above figures represent 10-year averages, except for the Little America III figure, which represents 18 years. They also represent large areas, which vary considerably in detail.

Snow Metamorphism

To learn more about the metamorphism of snow—the alterations of the crystals resulting from an assortment of physical phenomena, some of which are referred to below—control pits were dug at IGY Little America Station; these were re-excavated periodically to correlate snow metamorphism with change of season. Winter snow was characteristically fine-grained, closely-packed, and in relatively thick layers. Summer snow was coarse-grained, loosely-packed, and thin-layered.

Melt Crusts: At relatively-warm IGY Little America Station, melt crusts about 1 cm thick were formed, as well as other

obvious melt features. However, the origin of milky 2-mm crusts, found not only at Little America Station but also on the very high, very cold Victoria Plateau, is less certain. Most observers felt that these resulted either from contact-freezing, at the surface, of super-cooled rain or mist, or, perhaps, from insolation (direct radiation from the sun).

According to P. A. Shumskii, chief Soviet glaciologist in the Antarctic, these 2-mm crusts may be formed by the sun's rays penetrating vertically-oriented snow crystals along the c-axis (the vertical axis), causing melting within and at the base of the crystal—a "greenhouse" effect. Examination of these milky crusts (with a hand lens) on the Victoria Plateau showed the bottom side of the crusts to be straight and regular, possibly from the melting and joining of crystal bases. The tops were serrated, as might be expected in a group of hexagonal crystals. This was in keeping with Shumskii's views, but if basal melting does occur, vapor figures (bubble-like cavities formed within an ice crystal by the change in volume resulting from internal melting) should be found inside some of the crystals. None were observed.

This greenhouse theory, if later proved correct, would provide an excellent summer snow indicator for the vast Antarctic highland area, where the usual summer melting phenomena are nonexistent. These crusts could not form in the absence of sun during the long polar night, whereas the summer surface is rarely without a 2-mm crust of some kind.

Grain-Size Determinations: The melt crusts also affect grain size in the underlying snow layers. Examination of older layers reveals considerably greater grain size than in the newer layers.

This grain-size phenomenon, and its manifestations in ramsonde (the ramsonde measures snow hardness) and density tests, is the only stratigraphic indicator found thus far in the snow pits of the high plateau

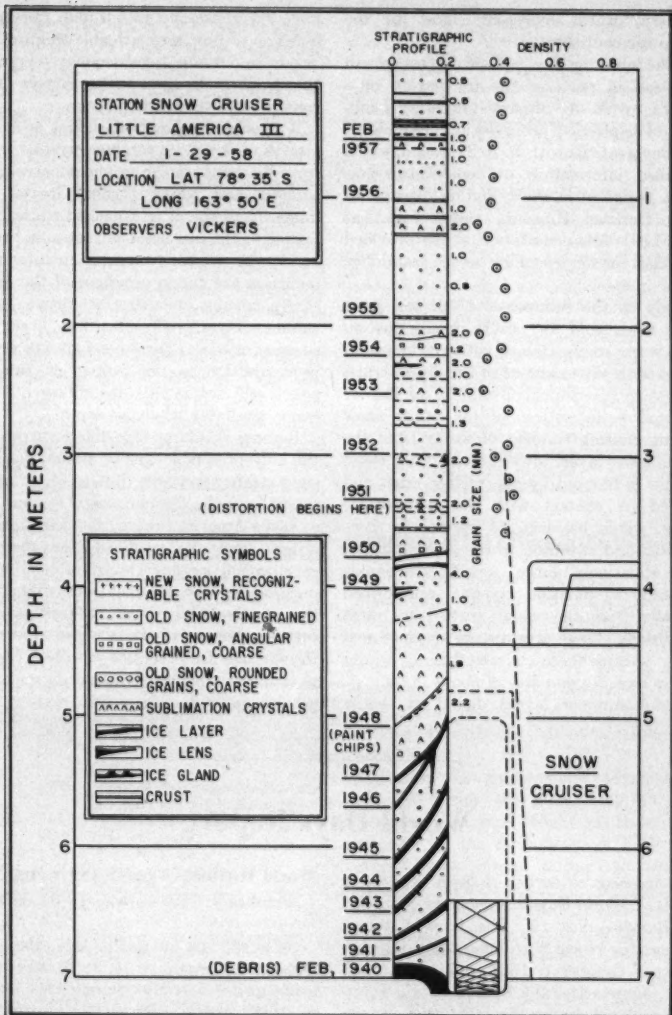


Fig. 4. Profile of Snow Stratigraphy at Little America III. Snow cruiser and debris at 1940 level provide a benchmark to check stratigraphic interpretations. Distortion below 3.4-m level resulted from unnatural melting caused by presence of snow cruiser. Circled dots represent measured snow densities, keyed to scale at top right; dashed line projects density profile downward.

country, which represents most of the Antarctic continent.

(The following discussion of crystal growth is based in part on the translation of a report by A. A. Shakov providing background on physical processes in a snow cover, on conversations with P. A. Shumskii, which supplied information on temperature-gradient variation in snow, and on discussions with Herfried Hoinkes, meteorologist at IGY Little America Station, which provided the basis for the reasoning on the instability of air in snow.)

Only in the summer and fall are there days when cold air occurs in conjunction with warm snow. This condition, when combined with the existence of the 2-mm crust, results in mechanical instability of the air trapped in interstices of the upper snow layers, causing transfer of vapor from the warm lower layers toward the surface. Here, the air is blocked by the surface crust and chilled by contact with the near-surface snow, which has lost its warmth by conduction and radiation to the overlying cold air. Relatively large, readily-identifiable crystals (sublimation crystals) are formed directly from the vapor created by these conditions. These crystals are about .8 mm long, whereas those characteristic of winter layers have a grain size of about .3 mm.

Older summer layers, found at depth,

have grain sizes up to 5.0 mm, raising the question of how they are able to grow from .8 mm to 5.0 mm in subsequent years when they are no longer at the surface where contact with cold might occur.

A possible explanation is that additional growth of the older summer crystals results from the temperature gradient between the summer and winter layers. Greater conductivity of the closely-packed winter snow (owing to the increased surface-area contact and to the smaller volume of air interstices) increases the energy gradient of the winter snow, causing molecular migration to the summer layer and a further growth of summer crystals. The second growth process is in addition to, not instead of, the first, which still occurs with instability but with lesser gradients when at depth.

Because this grain-size difference provides the only present means of annual dating of snow strata applicable to most of Antarctica (apart from the warmer coastal regions, such as Little America, where other stratigraphic criteria may be used) reinforcement by geochemical methods is desirable. For this purpose, tritium samples were taken from the positively-identified 1939-40 layer at Little America III. It is hoped that when the samples are processed it will be possible to reinforce conclusions based on the stratigraphic methods now in use.

World Days Report

References to earlier *Bulletin* reports on the IGY World Days Program are contained in *Bulletin No. 19*. The present report reviews the World Warning Agency decisions between October 1, 1958, and January 31, 1959, summarizes the Special World Intervals declared during the IGY, and outlines a successor program, the World Days Program for the International Geophysical Cooperation—1959.

World Warning Agency Decisions, October 1, 1958—January 31, 1959

As in the last quarter of 1957, the period October 1–December 31, 1958, was low in geomagnetic activity. During this interval in 1958, seven geomagnetic disturbances were observed, only one of them severe. November 1958, only the second month during the IGY in which no geomagnetic

storms were recorded, was the quietest month of the IGY with respect to geomagnetic activity.

Six periods of Alert were declared, two in each of the three months. Five of the seven geomagnetic disturbances occurred during three of these periods of Alert. The three other Alerts, including the two in November, were not followed by geomagnetic storms. There were three Special World Intervals (SWI), one in each month, totaling seven days. One SWI was not followed by a storm, but the other two were followed by the two most severe geomagnetic disturbances of the three-month period.

January 1959 was relatively quiet in terms of geomagnetic activity. Only two geomagnetic storms occurred, both minor. Three periods of Alert were declared during the month, and there was one SWI lasting two days.

The following is a list of Alerts, SWI, major flares, and geomagnetic disturbances for the period October 1–December 31, 1958; the Alerts and SWI are numbered consecutively from Alert #34, which ended on September 18, and SWI #18, which ended on August 28:

Oct	3	1600	Alert #35 starts
	6	1600	Alert #35 ends
	14	1600	Alert #36 starts
	22	0315	Magnetic storm begins
	23	0001	SWI #19 starts
	24	0730	Severe magnetic storm begins (while storm of Oct. 22 still in progress)
		1410	Class 3 flare; slow ionospheric drop-out and gradual recovery
	25	01XX	Magnetic storm ends
		2359	SWI #19 ends
	26	1600	Alert #36 ends
	27	15XX	Magnetic storm begins
	28	1505	Class 3 flare
	29	04XX	Magnetic storm ends
	31	0950	Class 3 flare; sudden ionospheric drop-out and gradual recovery
Nov	14	1600	Alert #37 starts
	16	1600	Alert #37 ends
	24	1607	Class 3 flare
	25	1600	Alert #38 starts
	26	0001	SWI #20 starts
Dec	27	2359	SWI #20 ends
	30	1600	Alert #38 ends
	4	0035	Magnetic storm begins
		1600	Alert #39 starts

	5	04XX	Magnetic storm ends
	7	1600	Alert #39 ends
	10	1600	Alert #40 starts
	13	0001	SWI #21 starts
		0002	Magnetic storm begins
	14	06XX	Magnetic storm ends
		2359	SWI #21 ends
	15	1120	Class 3 flare
		2022	Magnetic storm begins
	16	1600	Alert #40 ends
		21XX	Magnetic storm ends
	17	1820	Magnetic storm begins
	18	14XX	Magnetic storm ends
	31	1656	Class 3 flare; sudden ionospheric drop-out and gradual recovery
Jan	1	1600	Alert #41 starts
	3	1600	Alert #41 ends
	5	0136	Magnetic storm begins
	7	09XX	Magnetic storm ends
	9	1459	Magnetic storm begins
	10	1600	Alert #42 starts
	11	02XX	Magnetic storm ends
	14	1600	Alert #42 ends
	21	1700	Class 3 flare; sudden ionospheric drop-out and gradual recovery
	22	1600	Alert #43 starts
	24	0001	SWI #22 starts
	25	2359	SWI #22 ends
	29	1600	Alert #43 ends

Summary of SWI During the IGY

SWI were declared by AGIWARN 22 times during the IGY, totaling 47 days. The declarations were followed by geomagnetic disturbances in 16 cases, with two disturbances occurring in each of two of these cases. One SWI was initiated after a geomagnetic storm had started, and five SWI, totaling nine days, did not include disturbances.

Of the 55 geomagnetic disturbances recorded during the IGY, only 15 were classified as severe. Eight of these were preceded by the declaration of SWI. One severe storm began during an already successful Interval (one for which geomagnetic and other associated terrestrial effects had already been recorded) and another, in September 1957, was missed intentionally because several severe storms had already been successfully predicted during the month and it had been previously agreed to limit the number of SWI called in any month. In the remaining five cases, storms were missed because the solar events did

not suggest storms of great magnitude. One of these, unfortunately, was among the most severe storms observed during the IGY.

During six of the 18 months of the IGY (July and November 1957, and July, August, October, and September 1958) SWI were declared prior to the onset of the most severe disturbance of the month. In August 1957 and in March and June 1958 the initiation of Intervals preceded the month's second most severe disturbance. No geomagnetic storms were recorded in January and November 1958, and only one minor storm was observed in each of October and December 1957 and in April 1958.

World Days Program for IGC-1959

A program for World Days, Alerts, and Special World Intervals during the International Geophysical Cooperation—1959 has been put into effect. It represents a modification and simplification of the program carried out during the IGY. Figure 5 is the final calendar of World Days for IGC-1959.

Under IGY, the only kind of Alert was a world-wide one, declared when high solar activity indicated the probability of significant geophysical effects. The IGC plan, on the other hand, calls for regional Advance Alerts after the beginning of outstanding geophysical events; on the basis of these, the World Warning Agency (AGIWARN), operated by the National Bureau of Standards at Fort Belvoir, Va., then decides whether to declare a world-wide Alert or Special World Interval.

Regional Advance Alerts: Provision is made in the IGC World Days Program for four kinds of regional Advance Alerts—Solar Flare, Magnetic Storm, Cosmic Ray Increase or Decrease, and Auroral. The Advance Alerts are issued at any time of the day as soon as possible after the beginning of one of these geophysical events meeting the established criteria, as follows:

Solar Flare—Issued whenever a solar flare of median importance (2+) or greater has been reported.

Magnetic Storm—Whenever a significant magnetic storm, K-index of 5 or greater at a middle latitude station, has begun. (The K-index expresses geomagnetic activity in terms of a scale ranging from 0, or very quiet, to 9, or extremely disturbed.)

Cosmic Ray—Whenever an outstanding increase or decrease in cosmic ray flux has been observed.

Auroral—Whenever a magnetic storm in middle latitudes has reached a K-index of 7 or whenever selected auroral stations report the presence of an outstanding aurora.

Each Regional Warning Center (RWC) may issue an Advance Alert within its region as soon as the phenomenon is recognized and the RWC is satisfied it meets the established criteria. The Advance Alert is issued by telegram in a standard text form. It is distributed promptly within the originating region and is also sent promptly to other RWCs for distribution, if practical and expedient, within their respective regions. The Advance Alert messages serve both as an aid in the observing programs of individual stations within the regions and as advice to the World Warning Agency on the declaration of world-wide Alerts and SWI.

The text for Advance Alert messages includes the reporting station, the type of event, and the date and time of the event. The following are some sample Advance Alert messages:

- (a) ADVANCE GEOPHYSICAL ALERT KOKOBUNJI SOLAR FLARE 280010Z.
(This means a solar flare of importance 2+ or greater was observed on 28th day of month at 0010 UT by Kokobunji.)
- (b) ADVANCE GEOPHYSICAL ALERT NIZMIR MAGNETIC STORM 291900Z.
(This means NIZMIR recorded beginning of significant magnetic storm, K-index of at least 5, on 29th day at 1900 UT.)
- (c) ADVANCE GEOPHYSICAL ALERT ZUGSPITZE COSMIC RAY DECREASE 061130Z.
(This means the nominal time of an unusual cosmic ray flux decrease was 6th day at 1130 UT at Zugspitze.)
- (d) ADVANCE GEOPHYSICAL ALERT CORNELL AURORA OBSERVED 070230Z.
(This means outstanding aurora observed 7th

International Geophysical Cooperation 1959 Final Calendar

1959 JANUARY 1959

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
		1	2	3		
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

1959 FEBRUARY 1959

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

1959 MARCH 1959

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

1959 APRIL 1959

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
		1	2	3	4	
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

1959 MAY 1959

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

1959 JUNE 1959

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

1959 JULY 1959

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
		1	2	3	4	
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

1959 AUGUST 1959

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29

1959 SEPTEMBER 1959

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

1959 OCTOBER 1959

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
			1	2	3	
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

1959 NOVEMBER 1959

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

1959 DECEMBER 1959

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

1960 JANUARY 1960

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

- ③ Regular World Day
- ⑧ Regular World Day with highest priority
- ⑨ Regular World Day with unusual meteoric activity
- ⑩ Regular World Day with highest priority and unusual meteoric activity
- ⑫ Day of total eclipse

Regular World Interval (RWI)

17	18	19	20	21
22	23	24	25	26
16	17	18	19	20
21	22	23	24	25

Regular World Interval (RWI)

World Meteorological Interval (WMI)

Fig. 5. Final World Days Calendar for IGC-1959.

day at 0230 UT at Cornell University, Ithaca, N. Y.)

- (e) ADVANCE GEOPHYSICAL ALERT AGI-WARN AURORAL-INFERRED MAGNETIC STORM 070230Z.

(This means beginning of significant magnetic storm, K-index of 7 or greater, recorded 7th day 0230 UT AGIWARN. Auroral displays should be expected.)

World-Wide Alerts and SWI: On the basis of these Advance Alerts from Regional Warning Centers, the World Warning Agency decides whether to declare a world-wide Alert in one or more of the following categories: Magnetic Storm, Cosmic Ray Increase, Aurora. (Solar Flare and Cosmic Ray Decrease Alerts are only distributed regionally.) It may simultaneously declare an SWI, during which laboratories and stations intensify their observations.

World-wide Alerts and SWI are declared by a Warning Message issued by AGIWARN at 1600 UT (Universal Time, same as Greenwich Civil Time) on any day when geophysical phenomena in the preceding 24 hours meet the stated criteria. On other days, no Warning Message is issued (although a dummy message may be circulated over some distribution networks for a daily check of communications). The world-wide Alert messages issued by AGIWARN are in standard texts similar to those of the Advance Alerts but bear a serial number and, when appropriate, the time and date of the beginning or ending of an SWI or instructions to continue one.

Warning Messages are broadcast by the National Bureau of Standards radio station WWV (Washington, D. C.), by WWVH (Hawaii), and by certain other standard-frequency broadcast stations. A symbol in

Morse Code indicates the "State of Warning" at the time of each broadcast. This symbol is sent very slowly so that it may be recognized by scientists who are not specialists in radio-telegraphy.

Since time must be allowed for the Warning Message to reach the broadcast station, the "First Broadcast" to take into account a Warning Message will be made by WWV, at 1604 and repeated twice hourly at 04 and 34 min after the hour. WWVH's First Broadcast will be at 1714 and its repeat broadcasts will come at 14 and 44 min after the hour.

The following are the State of Warning symbols used in Warning Messages announcing world-wide Alerts:

- a) AGI-AAAAA An Alert was declared at 1600 UT (type not specified)
- b) AGI-(Three extra long dashes) SWI in progress
- c) AGI-EEEEEE No Alert declared at 1600 UT

The symbols broadcast as a consequence of each variety of Warning Message are given below (the introductory parts of text and symbol have been omitted in this table):

Warning Message Text	State of Warning Symbol	Remarks
a) Magnetic Storm (time*)	AAAAA	broadcast for 24 hrs. only
b) Aurora (time*)	AAAAA	broadcast for 24 hrs. only
c) Cosmic Ray Increase (time*)	AAAAA	broadcast for 24 hrs. only
d) [Alert message as in (a), (b) or (c)] plus Start Special World Interval	(Three extra long dashes)	

* Time (UT) of onset of phenomenon.

IGY Bibliographic Notes

This is the tenth of a series of bibliographic notes on IGY programs and findings. The references are selected largely from an IGY bibliography under preparation in the Science and Technology Division of the Library of Congress. (An interim bibliography prepared by the Library and published by the National Academy of Sciences, with support by the National Science Foundation, is available from the Academy for \$1.00.)

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IGY BULLETIN

A monthly survey of programs and findings of the International Geophysical Year and International Geophysical Cooperation-1959 as related primarily to United States programs

Meteorological Studies in the Antarctic

The following report is based on a paper presented by Gordon D. Cartwright, Coordinator of International Activities, US Weather Bureau, at the IGY Symposium of the 125th Annual Meeting of the American Association for the Advancement of Science, Washington, D. C., December 29-30, 1959.

The great expansion of meteorological observational facilities in the Antarctic during the IGY has resulted in much new knowledge of weather patterns and of the general atmospheric circulation in this remote, previously little-known region of the earth. This new knowledge represents a substantial beginning to a full understanding of Antarctic and Southern Hemisphere weather and climate.

The important role played by weather and climate in the modification of continents, largely through erosion processes, is well known. In the Antarctic, however, there exists a large, continent-sized region whose present configuration and broad features are more directly the result of weather and climate than of any other factor. Moreover, its subsequent modifications are likely to stem primarily from climatic changes. Thus, an additional challenge is presented to meteorologists to assist in unravelling Antarctic physical history.

Scope and Organization of Program

The meagre observations of earlier Antarctic expeditions, scattered widely both in

time and space, hinted at strange weather phenomena not observed in other parts of the world—mysterious pressure waves, baffling suddenness of Antarctic storms, great persistence of hurricane-force winds in some areas, extremely low pressures over long periods during the year, and others.

Basic data were needed to provide the answers. Hence, in spite of the uniqueness of the setting, well-tried kinds of measurements dominated the thinking of IGY planners. As a result, standard synoptic weather observations were made from representative points throughout the Antarctic.

Some 50 IGY stations made regular observations of surface weather at least four times a day. This represents a minimum of 100,000 observations scattered over the continent during the 18-month IGY period. Addition of twice-daily upper-air soundings at 16 stations to an average height of about 20 km—totaling over 300,000 discrete observations at various levels—further enlarges the scope of the data. Added to these are observations of solar radiation received at the surface, made at 28 stations, and data from micrometeorological studies.

Even this mass of information provides only a scant measure of the complexity of the immense processes at work in such a fickle medium as the lower atmosphere. However, these observations have enabled meteorologists, for the first time in history, to construct charts showing broad circulation patterns at various atmospheric levels

above the Antarctic. (Unfortunately, the virtual absence of similar observations over the sub-Antarctic oceans handicaps efforts to link these circulation patterns with those of the temperate regions of the Southern Hemisphere. Filling this gap will be one of the important tasks of the post-IGY years.)

Some Preliminary Results

Analyses of data thus far suggest that Antarctic weather can probably be explained by the same basic relationships existing elsewhere over the globe.

Continental-Oceanic Exchange: It seems clear that a great continental-oceanic exchange of air goes on in the Antarctic throughout the year, but with increased intensity during the winter. This exchange is intimately related to the complex system of low-pressure areas coursing around the continent, about 300 mi off its edge.

The atmospheric circulation resulting from these pressure systems forces warm, moist air at intermediate and higher levels to rise up over the edges of the continent and penetrate far into the interior. This process produces much of the snowfall over the continent. Above the high interior plateau, the air is cooled, eventually becoming part of the relatively stagnant, high-pressure areas predominating over the plateau, especially in East Antarctica. As it settles, the frigid air moves, partly by gravity flow and partly as a result of the general distribution of atmospheric pressure, back down the slope and is again caught up in the low-level circulation of the belt of cyclones circling the continent.

While this is now an accepted description of the fundamental weather processes prevailing over both polar regions, IGY programs have for the first time given a factual basis to the Antarctic picture.

Storm Tracks: The day-to-day preparation of synoptic weather charts for most of the Antarctic during the IGY has brought out two important facts: 1) storms seldom penetrate into the high interior of East Ant-

arctica; 2) storms frequently cross the continent over what may be a great continental trough stretching from the Ross to the Weddell Sea.

When these facts are considered together they suggest that the pole of Antarctic circulation is some distance from the geographic South Pole, just as is the main mass of the continent itself. This single conclusion, elaborated by much more data, can be of great significance to forecasting for Southern Hemisphere countries, especially Australia and South America. The further observation that the major storm tracks seem to divide at the Ross Sea area, some continuing over the South Pacific and others crossing Antarctica, however, somewhat complicates the picture for South America. This may be one of the most significant features of Antarctica circulation brought to light by the IGY Antarctic meteorological program (see Fig. 1).

The tendency of low-pressure areas to develop or stagnate in the great Antarctic embayments of the Ross and Weddell Seas was already postulated before the IGY began. Much more is now known about the extent of these features, which may resemble their Northern Hemisphere counterparts—the semi-permanent lows in the Gulf of Alaska and near Iceland.

The existence of the persistent area of high-pressure air over the high plateau of East Antarctica was also postulated prior to the IGY. This picture is now supported not only by the complex of weather data taken at a number of points in East Antarctica but also by the discovery of a vast area of fluffy snow in this central highland region of the polar plateau; the snow must have fallen under conditions of light winds over long periods of time.

The extent to which these features of the Antarctic circulation are exclusively Antarctic conditions, rather than a result of the broader geographical circumstances of the entire Southern Hemisphere (e.g., the relative positions of major land masses),

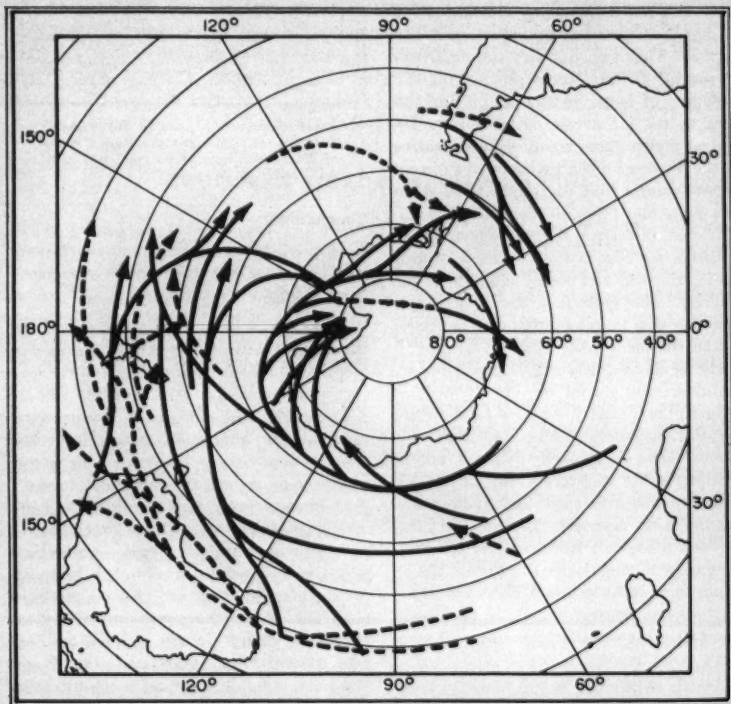


Fig. 1. Tracks of Surface Systems in the Antarctic Region, Winter 1967. Solid lines represent cyclonic systems, dashed lines anticyclonic. Compiled at IGY Antarctic Weather Central.

may be of great significance to Southern Hemisphere forecasting.

Weather and the Shape of the Ice Sheet: A Soviet meteorologist has theorized that the persistence of weather features in particular areas, specifically, the blocking of the movement of cyclonic storms by ridges of high pressure, has favored the outward growth of the continental ice sheet at certain points. He also applied this idea to the distribution of sea ice outward from the edge of the continental ice sheet and finds that, near USSR Mirny Station, aircraft observations support his conclusions.

Data gathered at Soviet IGY stations in East Antarctica indicate that the most persistent strong winds are found far up the slope of the ice sheet, about $\frac{1}{3}$ of the way between the coast and the central plateau. This results, no doubt, from the broad gravity out-flow of cold air from the high central plateau. These wind observations were supplemented by studies of the size and orientation of sastrugi (irregular snow-surface features formed by wind action).

In a Soviet glaciological traverse from the coast to the interior of East Antarctica, a progressive increase in the height of sas-

trugi was noted, reaching a maximum of $2\frac{1}{2}$ m about 260 km from the coast (see Fig. 2). This suggests that an interplay of several factors—temperature gradient, steepness of slope, stretching of the flow lines as the air moves outward from the central plateau, and compressional heating as the air flows down the slope of the continent—results in a maximum wind speed at a particular place on the slope.

The characteristic distribution of snowfall from the edge of the continent towards the interior was also observed on the Soviet traverse. The pattern found (Fig. 3) is probably also representative of other parts of the continent where the topography is fairly regular and undisturbed by mountain chains or deep glacial valleys.

Since the primary sources of moisture are the surrounding seas, and since the steeply rising slopes of the ice sheet tend to precipitate the moisture from air masses forced to rise over them, the finding that accumulation decreases towards the interior seems logical. However, the question then arises of why the ice sheet is not thickest, or highest, at its edge. There are probably several reasons why it is not; some are: 1) Higher velocity winds near the edge carry large quantities of snow out to sea; 2) higher temperatures and more sunshine cause more melting and evaporation of snow near the edge of the continent than in the interior; and 3) seaward movement of the ice sheet is more rapid near the edge.

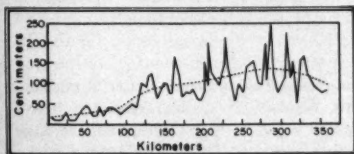


Fig. 2. Variations in Height of Sastrugi Between the Coast and the High Plateau of East Antarctica. Solid line represents actual heights, dotted line represents average heights. The increase in sastrugi height toward the interior reflects the increase in wind speeds. From material compiled by P. A. Shumskii.

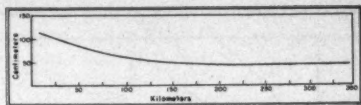


Fig. 3. Thickness of Annual Snow Layers Between the Coast and the High Plateau of East Antarctica. From material compiled by P. A. Shumskii.

Conclusions

The following preliminary conclusions may be drawn from IGY Antarctic meteorological data thus far analyzed:

- 1) A continuous, year-round exchange takes place between the warmer oceanic air and the cold air from the interior of the icecap, with increased intensity in the winter.
- 2) A complex system of low-pressure areas circles Antarctica about 300 miles from its borders, supplying warm air to the continent at intermediate and high levels.
- 3) Storms rarely penetrate into the high interior plateau area of East Antarctica.
- 4) Storms regularly cross Antarctica over the trans-continental trough believed to exist between the Ross and Weddell Seas.
- 5) The major Antarctic storm tracks appear to separate north of the Ross Sea area, some crossing Antarctica in the trough area and others continuing eastward over the South Pacific.
- 6) The "pole" of Southern Hemisphere circulation appears to be within an area of persistent high pressure over the high, central plateau of East Antarctica at some distance from the geographic South Pole.
- 7) There is a tendency for low-pressure areas to stagnate or to develop in the Ross Sea and Weddell Sea embayments.
- 8) The most persistent winds appear to exist over the icecap of East Antarctica about $\frac{1}{3}$ of the distance between the coast and the high, central portion of the plateau.

IGY meteorologic data are also helping to outline mechanisms that may have brought about the present physical configuration of Antarctica. Obviously, there is

an intimate and complex connection between weather factors and the original geologic features as well as with subsequent glaciological processes. As the volume and

scope of data from all three disciplines grow, a gradual unfolding of the long history of formation, growth, and change of the Antarctica ice mantle can be anticipated.

Ice Drift in the Arctic Ocean

The following report is based on a paper given by Irene M. Browne of the Geophysics Research Directorate, US Air Force Cambridge Research Center, at the IGY Symposium of the 125th Annual Meeting of the American Association for the Advancement of Science, held in Washington, D. C., December 29-30, 1958.

Study of Arctic Ocean ice movement provides information on the interaction of air and ocean not obtainable elsewhere, makes it possible to compare direct measurements of permanent ocean currents with concepts of these currents derived by analysis of hydrographic data, and may permit prediction of ice movement, thus aiding navigation in the Arctic Basin. The primary forces affecting ice drift are wind friction over the ice surface, friction between the ice bottom and the water, the Coriolis effect (the tendency of movement to be deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere, owing to the earth's rotation), and internal stresses within the ice itself.

Prior to the IGY, most data on Arctic Ocean ice drift were obtained by isolated expeditions (on some of which ships were intentionally allowed to become frozen into the ice pack), by Soviet drifting stations, and by a US scientific station on ice island T-3 (Fletcher's Ice Island, later the site of IGY Drifting Station Bravo). During the IGY, drift data were obtained mostly from scientific stations established on the floating ice. US-IGY Drifting Station Alpha was on a ten-foot-thick ice floe and Station Bravo is on Fletcher's Ice Island. (*Bulletins*

1, 2, 6, 12, 16, 17, and 22 contain additional information about the US-IGY drifting stations and their scientific programs.)

This report is based primarily on a preliminary survey of drift information obtained during the first 12 months of the IGY. Basic data were supplied by scientists of the Lamont Geological Observatory and Woods Hole Oceanographic Institution, under contract to the Air Force Cambridge Research Center, and of the Fisheries Research Board of Canada, who conducted investigations at the drifting stations; the analyses were carried out by Irene M. Browne at the Cambridge Research Center.

General Character of Ice Drift

The general character of ice movement in the Arctic Ocean is evident from the drift patterns of US and USSR drifting stations and of ships accidentally or intentionally frozen into the ice. Figure 4 shows some of these drifts.

The *Fram* Expedition of 1893-96, led by the Norwegian explorer-scientist Fridtjof Nansen, was the first major scientific expedition to the Arctic Ocean. Nansen permitted his specially-designed ship to be frozen into the pack ice on the Siberian side of the Arctic. In the next three years, during which many scientific studies were made, the *Fram* drifted with the ice pack completely across the Arctic Basin and was finally freed from the ice in the Greenland Sea, near Svalbard.

The Soviet ship *Sedov*, in a similar venture, was frozen into the ice in the same region in 1937. Its course paralleled that of

until mid-September. The direction was reversed until mid-December and then the drift was in the general direction of Greenland. The distance between Station Alpha and North Pole 7 averaged 150 mi. The harmony of these drift patterns demonstrates quite distinctly the characteristic movement of the ice in this region.

Observations made thus far indicate that, in general, the ice drift follows closely the sea-level atmospheric pressure systems, that the clockwise orbit of ice movement on the North American side of the Arctic Ocean corresponds to the major motion of the surface currents, and that the rate of transport of surface waters and the rate of the observed ice drift in this region are on the same order of magnitude.

Wind Drift of the Ice

It appears certain from these IGY investigations that the main driving force for the drift of Stations Alpha and Bravo was the wind. When winds were strong and predominantly from one general direction, drift was relatively rapid and approximately before the wind (with some deviation to the right, as explained below). When winds were light and variable in direction, net movement was small.

Relationship to Atmospheric Pressure Systems: According to the Soviet theorist, Zubov, the Arctic Ocean ice pack moves parallel to the surface isobars (lines of equal atmospheric pressure); the higher pressures are to the right by about 1/100 of the geostrophic wind speed (wind deflection due to the earth's rotation). Figure 5 presents the mean sea-level pressure contours by quarters for the first twelve months of the IGY over the Arctic. Also shown are vectors representing the drift of the four stations during each period. Isobaric contouring in these high latitudes is subject to some error owing to the scarcity of meteorological stations, yet the conformity of the drift patterns to the pressure systems is evident.

In the first quarter, a low-pressure system situated north of the New Siberian Islands was responsible for the rapid northerly drift of Stations Alpha and North Pole 7. North Pole 6, located near the center of the low, and T-3, located between two pressure systems, were becalmed, as would be expected. The cyclonic system dissipated in the next quarter and was replaced by an intense high over the same general region. Correspondingly, the direction of ice movement was reversed, following the clockwise circulation of the anticyclone. This system persisted throughout the remainder of the 12-month period, during which North Pole 6 was in the region of strong trans-polar movement; Station Alpha and North Pole 7, after a period of southerly drift, were caught in a gradual movement toward the coasts of Canada and Greenland as the high moved across the Arctic Ocean; and T-3, first subjected to southeasterly flow, moved little during the rest of the period, when winds in general were shoreward.

Coriolis Effect and Drift Speeds: Beginning with the *Fram* expedition, it has been observed that the ice usually drifts to the right of the surface-wind direction in the Northern Hemisphere, owing to the Coriolis effect. Comparison of the predominant winds with the trend of Station Alpha's drift substantiates this observation. Over 90% of the drift angles (relative to wind direction) obtained for Station Alpha were oriented to the right of the surface-wind direction. The peak frequency is at drift angles between 30° and 50°, with a computed average of 33°.

Nansen first interpreted the deviation of the ice to the right of the wind as owing to the effect of earth's rotation. Later, V. W. Ekman provided a mathematical analysis which indicated that the angle of deviation of the surface current from the wind is 45°. The smaller value actually obtained for ice drift presents a problem. It has been attributed to internal ice resistance by some authors.

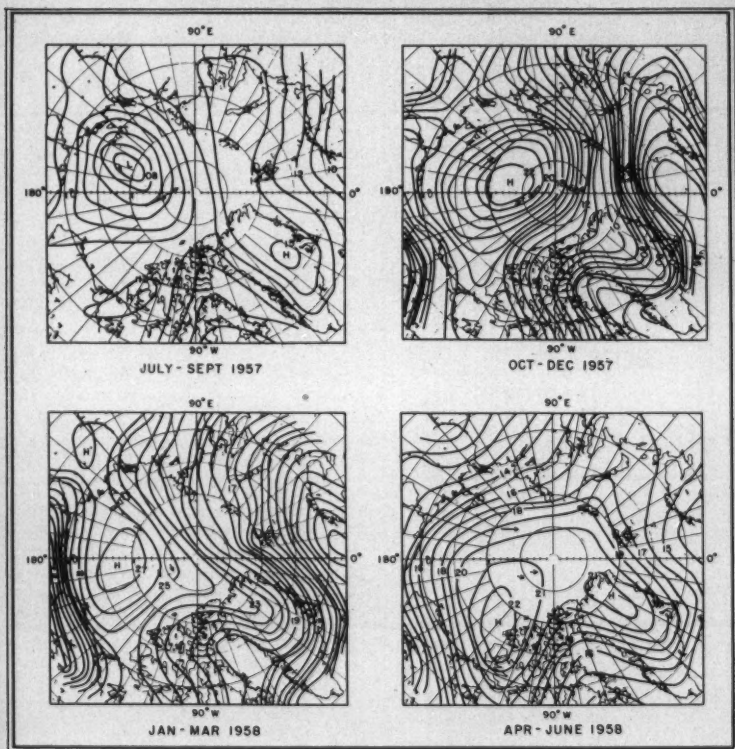


FIG. 5. Sea-level Pressure Contours over the Arctic, by Quarters from July 1957 through June 1958. Pressures in millibars (for actual values, add 1000 to numbers above 00 and 900 to numbers below); arrows are vectors showing direction and relative amounts of ice movement.

It was also found that over 60% of the time, the drift speed was 1/80th-1/40th of the surface wind speed. The average ratio was .0206, or about 1/50th.

The averages given above correlate well with the mean observations of angle deviation and drift-speed ratio found during the earlier expeditions, on which wind speeds were measured at heights of 6 or 8 m above the ice. A summary of these observations is given in Table 1.

TABLE 1

	Ratio of Ice Drift to Surface Wind Speed	Angle of Devia- tion of Ice Drift from Surface Wind Direction
<i>Fram</i>	.0182	28°
<i>Maud</i>	.0177	33°
<i>Sedov</i>	.0150	29°
T-3 (pre-IGY)	.0130	37°
<i>Alpha</i>	.0206	33°

The averages for the drift of T-3 are based on wind measurements at the higher

level of 10 m above the ice. Averages remained constant for both the pre-IGY and IGY movements of T-3, although there was a marked difference between the rate of movement in higher latitudes, where the ice is more closely packed, and in the regions of loosely packed ice nearer the coasts. In the higher latitudes, the island is locked tightly in the pack and is therefore strongly influenced by the rate of drift of the entire pack. Nearer the coasts, on the other hand, where the island is relatively free of the pack, its own large size probably has a greater effect on its movement.

Arctic Ocean Currents

Oceanic circulation must also be considered in analyzing the movement of the ice pack. The amount of hydrographic data for the Central Arctic is still limited but more is gradually being accumulated.

Hydrographic studies on Project *Skijump*, 1951-1952, indicated the existence of a giant eddy in the region north of Alaska (see *Bulletin No. 6*). The observed ice drifts conform to this circulation pattern. An analysis was made of the hydrographic data obtained from USSR drifting station North Pole 2, from ice island T-3 prior to the IGY, and from IGY Drifting Stations Alpha and Bravo. The results are given in Figure 6, which shows the dynamic height anomalies relative to the 600-decibar surface. (A decibar is the pressure exerted by a column of water one meter high. The dynamic height anomaly represents the deviation of the actual pressure surface from a level surface at the equivalent depth.)

If it is assumed that the 600-decibar surface is one of little or no motion, the surface-water movement will follow closely the contours of the sloping isobaric surfaces shown in Figure 6—the force of gravity moves the water down slope and the Coriolis force turns it to the right.

The addition of the IGY stations amplified knowledge of the circulation pattern and served to demonstrate that a closer

contouring interval in the Alpha region and a more complex contouring in the T-3 area existed than previously thought.

The average rates of circulation in kilometers per year between certain hydrographic stations have been computed and are also shown in Figure 6. These rates give an average time of ten years for circulation around the outer edge of the eddy, which compares favorably with the observed drifts of ice islands T-1 and T-3. The rate of surface movement between Alpha hydrographic station 4 and *Skijump* (the pre-IGY program on ice island T-3) station 3 is calculated as 895 km/yr; between *Skijump* station 7 and North Pole 2 station 12 it is 554 km/yr. Over this same general area, ice island T-1 in 1947 and 1948, and Station Alpha during the IGY, traveled in approximately the same direction at the average rate of 650 km/yr, which compares very

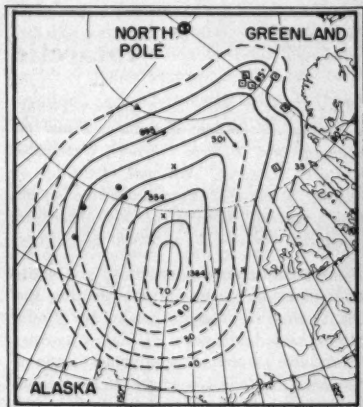


Fig. 6. Dynamic Height Anomaly in Arctic Ocean North of Alaska, Showing Circulation Pattern. Dots are NP-2 hydrographic stations; crosses are Skijump stations; small dots in squares are Bravo stations; and triangle is an Alpha Station. Arrows and associated numbers show drift direction and rate (in km/yr) between certain stations. Contour numbers are in dynamic millimeters.

well with the surface circulation computed from the available hydrographic data.

A small amount of current data was collected from Station Alpha. Analysis of these data shows that movement in the upper 16 m of the water corresponded to that of the ice in both speed and direction, with a small increase of speed with depth. Deeper current profiles and further information on daily ice movements were obtained during the summer of 1958. When analyzed, these data will help fill in the picture of water motion for this part of the Arctic Basin.

Statistical Investigations

In an effort to establish more clearly the nature of the forces affecting Arctic ice movement, certain statistical studies were made in addition to the direct measure-

ments and comparisons already described.

Both drift-speed/wind-speed ratios and angle deviations observed along the Station Alpha drift path were examined statistically for trends indicating permanent current effects. None were found. Instead, a general scattering of the data was evident for all wind speeds. This is not surprising in view of the complexity of some of the factors involved in the drift of the Arctic Ocean ice pack. Principal among these is the transmission, over distances as great as 100 mi or more in the closely-packed ice, of internal stresses originating in areas of convergence and divergence.

Data collected during the IGY occupation of the drifting stations may eventually lead to a fuller understanding of this and other factors influencing drift patterns.

Antarctic Plant Life

This report is based on a paper presented by George A. LLano, Secretary, Panel on Biological and Medical Sciences, Committee on Polar Research, National Academy of Sciences, at the IGY Symposium during the 125th Annual Meeting of the American Association for the Advancement of Science.

Observations and specimens of Antarctic plant life were obtained during the IGY to provide information on the kinds, growth, and distribution of plants in Antarctica, and to provide a possible means of estimating the relative length of time some of the land areas have been ice-free.

Members of traverse parties from IGY Ellsworth and Byrd Stations made botanical collections in previously unknown areas of West Antarctica. During the summer 1957-58 resupply operations, George A. LLano took specimens from accessible coastal areas in the McMurdo Sound region and around the IGY Hallett and Wilkes Stations.

McMurdo Area

LLano's comparisons of the flora on Hut Point Peninsula (thin but widespread and persistent moss and lichen) with that at Cape Evans (no lichens and mosses, but plentiful fresh-water algae in shallow ponds) led him to the tentative conclusion that the Hut Point area has been free of ice for well over 500 years, while Cape Evans has been exposed for a relatively short time. Large colonies of lichens were found on Hut Point within one foot of the edge of the permanent ice fields, suggesting that the ice front is now stationary. Both locations are on Ross Island, near the US Naval Air Facility.

Ross Island is of volcanic origin, and its ice-free areas stand out like slag heaps. At both Hut Point and Cape Evans the dark volcanic rock is highly absorbent to solar radiation and hence provides favorable conditions for plant growth. The rock on the Cape, however, crumbles very easily under

frost conditions, and is an unstable substratum for the development of slow-growing plants, particularly lichens. Within the Hut Point area itself, the small orange-colored lichen *Placodium* grew in the pits of the larger lava blocks, but not in rocks that appeared easily shatterable by frost action. In general, such rocks were free of plants.

Another factor favorable to plant growth at Hut Point is that the mosses and lichens there were provided with essential moisture, available as meltwater from the surrounding ice fields, snow flurries, or blown snow. Moreover, during the brief open-water period, sodium compounds from sea spray undoubtedly served in lieu of the nitrogen compounds furnished by bird rookeries at other locations. The many small balls of sponge spicules found even on the higher inland slopes support this view.

Hut Point contained several varieties of moss and lichen in addition to the *Placodium*. Two species of the crustaceous lichen *Rinodina* were found on larger, smooth-faced black boulders. On higher flats receiving a slow flow of water-saturated material, small but thick pads of moss largely covered with the lichens *Physcia*, *Rinodina*, *Buellia*, and *Lecanora* grew in the lee of raised ground or small rocks.

The algae-loaded ponds at Cape Evans were found to be considerably smaller than when mapped by Scott in 1910; some had disappeared entirely. Their former shorelines could be traced by the remains of dried-out, colorless masses of algae.

Ponds at Cape Evans had little or no ice cover when those at Hut Point were still completely frozen over. In the frozen ponds at Hut Point, the alga *Phormidium incrustatum* was found imbedded. However, the plants did not remain frozen and dormant, as might be expected. Those projecting above the ice surface absorbed enough heat to form small pits around themselves and melt any snow that fell around them. The plants then took up the resulting moisture and apparently carried

out photosynthesis, becoming soft, pliant, and deep green.

The *Rinodina frigida* found at Hut Point had a maximum diameter of 5 cm. In contrast, specimens up to 15 cm in diameter were seen above Taylor Dry Valley, 70 mi northeast, where they grew about 3000 ft above the valley floor, along a line that received daily snow flurries. To permit this large size, the substratum must have been ice-free for at least 1500 years.

Cape Hallett Area

The lichen vegetation on the summit of the headland near the joint US-New Zealand IGY Station at Cape Hallett, in East Antarctica, was luxurious out of all proportion to its surroundings. The summit, standing some 1500 ft sheer above Moubray Bay, consists of only 20-odd acres of bare land, almost completely hemmed in by massive ice fields. The ground is richly fertilized, however, owing to a rookery of 225,000 penguins (estimate by Carl Eklund, ornithologist and Station Scientific Leader at IGY Wilkes Station) at the base of the headland. A fine powder from the 1210-year-old guano deposit is raised by updrafts along the face of the slope to the summit. (The age of the deposit was determined by New Zealand scientists at IGY Hallett Station using carbon-14 techniques.)

The first lichens, bright-orange *Caloplaca*, always associated with guano deposits in polar regions, appeared some 200 ft above the rookery. Higher up, light-green *Neurospora*, the only fruticose (shrub-like) lichen in East Antarctica, was encountered growing in mats like short grass. On the reddish volcanic rubble of the summit, *Umbilicaria* was a dominant element.

Wilkes Area

The area around IGY Wilkes Station was biologically the richest of all those investigated. The dominant lichen, *Umbilicaria*, was well represented by the cosmopolitan *Umbilicaria decussata*, which in temperate regions is commonly found only

in the alpine zone and then sterile. In the Wilkes area, however, the plant is ubiquitous and fertile. *Neuropogon* and a great variety of crustaceous forms were also present. Mosses occurred in small pockets of soil, and many of the marginal snowfields were reddish or green with algae.

The wide variety and extent of cryptogamic flora (not producing flowers or seeds) suggested that the land area around Vincennes Bay on which Wilkes Station is located, has been exposed for a long time. Other growth-accelerating factors also exist there, however—in particular, the tempering effects of the nearby sea, often ice free even in winter, and many seabirds.

Inland Regions

On the IGY Ellsworth Station Traverse during the Antarctic summer of 1957–58, N. B. Aughenbaugh, H. A. Neuburg, and P. T. Walker collected two specimens of lichens and one of a fresh-water alga in the Dufek Massif of the Pensacola Mountains, at about 82°S. The alga, *Phormidium incrustatum*, was the dominant plant growth in a shallow, 75-ft wide, fresh-water pond. Much of the algae lay exposed in dry windrows above the water level.

Both lichens were crustaceous species and, with the algae, are representative of genera having wide distribution in polar regions. Both were young, immature specimens, undoubtedly only recently established. One, a *Rhizocarpon*, was found on a large quartz pebble immersed under approximately a foot of water in the shallow end of the pond. The other, a *Caloplaca*, was taken from a crack in gabbro rock (dark igneous rock) next to a small, receding snowbank. This small detail of habitat emphasizes the dependence of these plants on moisture, and, therefore, the great importance of meltwater for plant growth. No other evidence of plant life in the Dufek Massif was found by the traverse party, but it seems probable that closer examination over a wider area would reveal other lichens.

Support for this belief is found in the

extensive nature of the collections made in the Sentinel Mountains by D. P. Hale during the IGY Byrd Station Traverse of 1957–58. Hale collected some 60 species of lichens at a location (78°S) as far inland as that examined on the Ellsworth Traverse and isolated from other ice-free areas by a vast plain of very thick ice. Lichen genera found included *Caloplaca*, *Blastenia*, *Rinodina*, *Buellia*, *Hormiscium*, *Alectoria*, *Rhizocarpon*, and *Umbilicaria*. With the exception of the last-named, all are rock-encrusting species, common to the mountain areas of temperate zones as well as to the Arctic and Antarctic regions. Hale found no mosses, which apparently are more restricted in distribution than lichens, and quite possibly are altogether absent from the interior of Antarctica. The rigorous climate of the interior is not a deterrent, however, to the growth of lichens, which undoubtedly appear on ranges and peaks as far inland as the edge of the Polar Plateau, although few in species, gradually diminishing in numbers, and of dwarf size.

Conclusions

From the data thus far available, L. Lano draws these tentative conclusions:

1. It is not likely that flowering plants will be found in Antarctica, except at a few sites on the Palmer Peninsula, which reaches to about 62°S.
2. Non-flowering plants—algae, lichens, and mosses—have a remarkably wide distribution throughout the ice-free land areas. However, the cryptogamic vegetation of West Antarctica, and especially of the Palmer Peninsula region, is far richer than that of East Antarctica.
3. Terrestrial and fresh-water algae are probably the most widespread element of the Antarctic cryptogamic flora. One species, *Phormidium incrustatum*, is found in all persistent fresh-water ponds. The wide distribution of this alga may be attributed to the far-ranging skua's habit of bathing in fresh-water ponds.
4. Lichens have the second widest distri-

bution of all land plants and should be expected on all exposed land masses even deep into the interior.

5. Mosses appear more restricted in distribution but are common in coastal areas.

6. New plant colonies on exposed land may be brought about by some Antarctic birds, but many of the interior sites could not have been colonized by this means. However, the presence of birds and their nitrogenous deposits are important in accelerating polar-vegetation development.

7. With the exception of the short fruticose *Neuropogon* genus, the lichens of East Antarctica are all rock-, earth-, or moss-encrusting forms. Large, ornate forms common to the tundra of Arctic regions are conspicuously absent.

8. Cold is not the major inhibiting force limiting the establishment or growth of plants in the Antarctic. The cryptogamic vegetation is dependent upon a combination of insolation (direct solar radiation) and moisture, the latter not necessarily as seasonal precipitation. The addition of guano, as dust or through leaching, is a strong factor in growth.

9. Insolation during the light period of the austral summer builds up over the rocks and earth a shallow thermal layer which is quite independent of the ambient air temperature. During the growing season, the cryptogamic vegetation of the land exists under microclimatic conditions not too unlike those at comparable locations in temperate regions.

IGY Bibliographic Notes

This is the eleventh of a series of bibliographic notes on IGY programs and findings. The references are selected largely from an IGY bibliography under preparation in the Science and Technology Division of the Library of Congress.

IGY Bibliography

The first volume of the International Geophysical Year Bibliography is available from the Publishing and Printing Office, National Academy of Sciences, 2101 Constitution Avenue, N. W., Washington 25, D. C. Price \$1.00, postage prepaid. The 64-page volume contains 704 references.

The Bibliography is being compiled at the Library of Congress and is a joint project of the Library, the Academy, and the National Science Foundation.

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